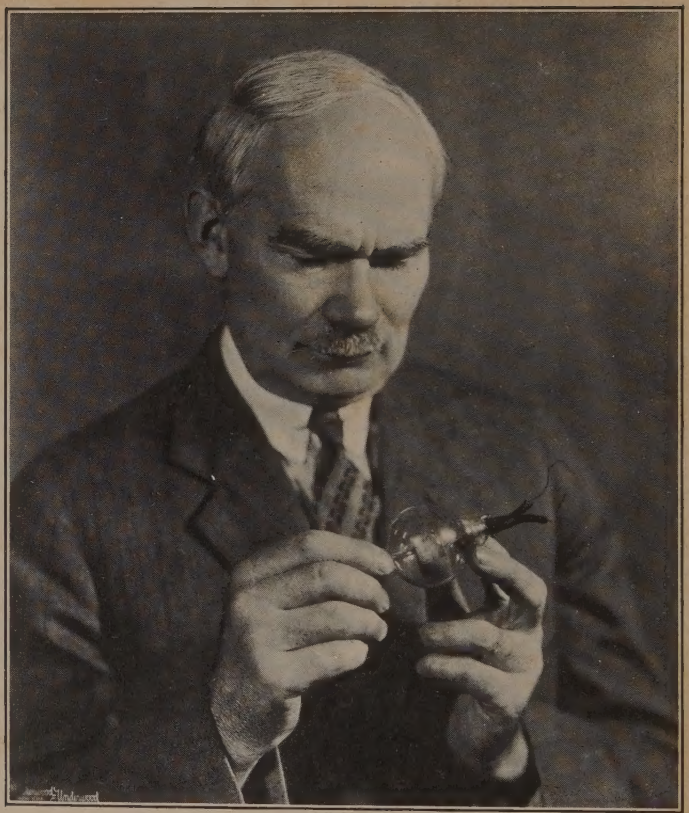
CONQUEROR OF SPACE

THE LIFE OF
LEE
DE FOREST

BY
GEORGETTE CARNEAL

A CONQUEROR OF SPACE



LEE DEFOREST

A Conqueror of Space

AN

AUTHORIZED BIOGRAPHY OF

THE LIFE AND WORK

OF

LEE DEFOREST

BY

Georgette Carneal

HORACE LIVERIGHT · NEW YORK

1 9 3 0

COPYRIGHT, 1930, BY GEORGETTE CARNEAL
MANUFACTURED IN THE U. S. A.

AUTHOR'S NOTE

For information contained in this biography, the author is chiefly indebted to Dr. deForest, whose accounts of the evolution of his own inventions, and whose history of his varied patents, supplemented by a complete written record in the form of diaries and note-books kept from his early boyhood, form the bulk of this story of his life and achievements.

The author also wishes to express her gratitude to William Arvin whose "Life and Works of Lee deForest," published in 1924 in "Radio News," supplied many invaluable details in the life of the inventor, as well as considerable information concerning the beginnings of radio not to be found elsewhere in the annals of that art.

THE AUTHOR

CONTENTS

PART I : Streets of the Past 1

PART II : Herr Hertz's Waves 49

PART III : The First Invention 89

PART IV : The Other Side of the Shield 135

PART V : The Axis of Radio 175

PART VI : The Phonofilm 279

PART ONE

STREETS OF THE PAST

I

ALL his life long Lee deForest has been wondering what made him an inventor: instead of a minister, a teacher, or just a man holding down a job somewhere. But he can find no answer, no matter how far he searches in the streets and feelings of the past.

Yet as far back as he can remember he has known, sometimes with a dreadful certainty, that this was his life's work, that he could no more change it or escape from it than he could change the color of his eyes.

There it is rearing its head at the far end of his memory. And, like the hint at the climax in the beginning of certain of the great books, all of his life is suggested in a first picture.

That first picture: It was Christmas morning in the dreary little town of Talladega, Alabama, in the year 1879. Christmas Day, like the day before Christmas and the day after Christmas, was a bleak, drab, not too friendly day. The mud of the streets outside was crusted with a hard surface, yet was not sufficiently frozen through to walk upon with comfort. The white light from the sky overhead streamed into the "parlor" in the front of the house, a big gloomy room that the deForest family could not afford to furnish.

Now that it was Christmas the dining room reflected a cheery Christmas atmosphere. The room was brighter than usual; the kerosene lamps were lighted. In the soft-coal grate a fire was burning. In one corner stood a tall pine tree, dangling candy canes tied with red ribbons, cheerful Santa Clauses, and here and there a still unopened gift. The mother of the three children sat at the head of the table, serving a more plentiful and interesting breakfast than usual, part of which she reserved for the hungry-eyed little Negro boys gathered round the fire, waiting to receive their Christmas gifts from their beloved pastor, the Reverend Henry deForest.

It was Christmas to be sure — but there was not a toy in the room. The presents the family had been able to provide were useful gifts: new hide shoes for the cold weather; woollen shirts; picture books for the two boys, Lee, six years old, and Charles, his brother; hair ribbons for their sister Mary. But toys, the little locomotives painted bright green that had made Christmas in the East — where were they now?

It was impossible to buy a manufactured toy in Talladega. In school the children had heard vaguely of bright new toys being shipped in from the North to the children of the wealthy, but this was a costly business, far beyond the means of the deForest family. And, since this was their first Christmas in the South, the children had not learned that they would receive no toys until after the pastor and his wife had ransacked the town of Talladega. In the funny shops down in the main street the number of manufactured objects they found could have been counted on the fingers of one hand: coarse sweat shirts, suitable for colored workers, hand-mowing machines for tilling the

soil, cans of paint for brightening the farm-houses, a few candles, spools of thread, and not much else. All of it reflecting the backward spirit of an agricultural community, consisting mostly of Negroes, whom these kind people had come down to educate and to uplift. And, returning tired and disheartened from this futile search, the pastor's wife peeped in at her children hard at work in the parlor.

"You'd better finish your locomotives," she said, glancing at the two broken down barrels, the pile of nails carefully stored in a corner, and the beginnings of several wooden block cars without wheels. The note of warning in her voice startled both the small colored assistants and Lee himself.

"Why?"

"The Talladega Santa Claus hasn't any toys."

No toys! The world went black, as out of it faded that bright picture of one's self moving new Christmas toys around in the parlor: excitement and color for a whole year. The children marshalled their forces in a desperate effort to finish their home-made block cars by Christmas Day. Wheels from last year's toys were carefully removed and the wire to attach them to the new cars found somewhere in the cellar. Christmas Eve meant bed and hence cessation from the building of the block cars; Christmas Day meant a chance to finish them before night.

Lee hurried away from the breakfast table with a corps of eager colored children for assistants. They had yet to fasten the wheels to the cars and make them move. Christmas night was coming — and coming too were colored and white girls and boys from the com-

munity. They would have their trains finished by then and show them off.

Hard work and noise in the long, empty, cold parlor. By noon the little workers had attached the wheels to the cars. They had to leave work then and eat their Christmas dinner, and take part in the celebration at Sunday school. By early afternoon they had reassembled. The girls provided strips of torn red ribbon to use for signals. The wheels were attached. Then Lee got behind this grotesque train of cars and pushed with all his young might — but the locomotive would not move an inch. The world went black again.

It stayed black on Christmas night when the children of Talladega flocked into the long cold parlor to see the toys. They pushed and pulled, but the homemade cars refused to budge. Mrs. deForest lit the lamps in the parlor. Those silent awkward toys gave the room a strange aspect.

"Why won't they go?"

"Make them go."

"Let's see them move."

But the cars stuck as if glued to the floor. The little wheels were too small for the heavy wood. Lee and his aides stood by, keeping stiff upper lips. The neighborhood children began to laugh. The young workmen said nothing. Red signals moved now and then in the cool air, and the sound of laughter increased the size of the lump in Lee's throat.

He stood it as long as he could. Then he went swiftly through the house and down the dark steps leading into the cellar. As he walked he had to feel his way. There was a box of matches on a table at the bottom of the steps. He found them and lit one of them.

There it was, the heavy twine that might help. He took it and came back up the steps. The children had begun to leave. Christmas would soon be over. Desperately, the small soiled hands attached the heavy twine to the engine, making three double thicknesses of twine upon which to pull. Then the children took hold. They pulled with all their might and suddenly, just as the last few onlookers were leaving, the locomotive began to move. The wheels turned grandly round as the boys walked across the floor. The skeptics wheeled round and stared.

The feel of those little cars moving behind the rope is still warm in the inventor's memory.

II

THERE was a note of sameness in the town of Talladega, of desires impossible to realize, that even the children recognized. It was an isolated group of dwellings in the heart of the southern black belt. In the early part of the nineteenth century, a frontier village inhabited by Indians. Life here would have been poor and lonely enough even had the deForest family enjoyed what activities went on in the homes of the whites, but they were ostracized, hated, isolated for their sympathy with the Negroes. When the Reverend Mr. deForest first received a call to become president of Talladega College, an institution founded by missionaries for the purpose of educating and uplifting the Negroes, he had deliberated long. It was a far call from the comfortable happy life of a minister's family in Muscatine, Iowa, from the big Congregational Church which numbered among its members the élite of Muscatine, from the roomy well-furnished mansion in which he lived, and from the streets filled with shops, many of them containing objects of wonder for little boys to see. Even without the feeling of obloquy that constantly oppressed the family during the long years of their life in Talladega, the town would have been difficult

enough; with it they were forever hungry for a taste of the outside world.

Lee's father and mother had met in Iowa. Both descendants of pioneers, both intensely religious, they found common cause in bringing the Gospel to the hardy folk of the corn belt. Lee's mother was the beautiful daughter of Alden B. Robins, descendant of John Alden of Mayflower fame. Her family had gone out to Iowa in 1850 to a crude frontier country to face rough living as members of the "Iowa Band," those devoted and fearless missionaries of the early days, whose influence made itself felt throughout the Western States. Miss Robins was one of the first graduates of Grinnell College and the most beautiful girl in the class. She was a talented singer and had not long led the choir in Dr. deForest's church at Council Bluffs before the choir leader and the young minister were married. Lee deForest was their first boy, born in the parsonage of the Congregational Church at Council Bluffs, Iowa, on August 20th, 1873. Two years later the family moved to Waterloo, Iowa, bringing Lee and Mary, a year older than Lee, with them. There Charles was born in 1878 and then there was a happy stay in Muscatine until finally Talladega was reached.

Day after Christmas at Talladega was a day like the day before Christmas: Lee had the "chores" to do. Wood to be piled under the shed outside the house; errands to be run, trips to and from the grocery store for a bag of potatoes, a pound of lard, or a gallon of kerosene.

He walked down streets of mud or cobblestones, past

churches, cool in summer when the scorching sun dried the blue grass sticking up between the cobblestones, warm in winter when the gutters were frozen over and the thin ice made a first-rate sliding board. Hardly a block without a church, clean and inviting, for spiritual consolation was the cry of the day, promises that beyond these muddy streets were streets of gold, beyond the common food they ate so hungrily was milk and honey. But what about things to do, excitement, toys?

If you went far enough down these crooked muddy streets you would see the Bingham Steam Saw Mill. Two blocks away was the Municipal Water Pumping Plant, a stone's throw from the cotton gin and press. Or you could go still farther beyond the last block of cobblestones, and await the daily arrival of the so-called "fast" express train at the station. Power and glory beating in your blood when it steamed in; emptiness again when it rolled out. It would be dark by then, just time enough to run home in the dark, listening to the hunting dogs on nearby farms, growling out their discontent, baying on into the night, and the exciting sound of the faraway train fading into an insignificant echo.

At home there was supper. Bible study, prayers, and bed. There was not much else.

Once a year a new kind of train puffed into the station. It was painted bright red, and bore all sorts of strange markings. In some of the cars, behind open bars, were melancholy lions, brilliant zebras, splendid white horses. The trains were opened up, and down the crooked streets of Talladega an army came marching. Men with drums; fat ladies; two-headed girls; wagonloads of animals. The circus had come to town.

In huge red letters appeared the name "Sells Brothers." The circus people pitched their tents, and all of Talladega, colored and white, sallied forth. All but Lee and Charley deForest. Their father believed that going to the circus would set a bad example to the Negroes. There was nothing of spiritual uplift in the circus.

Evening found the boy Lee down by the tents, an obscure little figure in patched pants and worn shoes, watching the crowds pour in. Once a beautiful lady rode out on a white horse. It was a bright picture: the sparkling silver flounces of her dress, the flowing mane of the horse, and pretty pink silk legs dangling down over the white flanks of her steed, moving in rhythm to the music. Lee's eyes grew big. All evening, in his loneliness, he remembered her.

The colored playmates would stay on at the circus grounds, buying popcorn and lemonade and watching the sights, but Lee soon grew tired of being on the outside. Inevitably he would return to the study, light the smelly oil lamp and turn the pages of his father's encyclopedia to pictures of the most fascinating objects in all the world: steam hammers, mechanical scroll saws, and a pageant of locomotives.

Little by little he was leaving the Talladega world behind, finding for himself another world of his own.

THE challenge of summer in Talladega sounded louder than ever on the Fourth of July. Then, even as at Christmas time, the children were thrown on their own resources. There were no fireworks in Talladega. As young patriots in the North, they had spent the weeks before the Fourth gathering and carefully stor-

ing in a dry place, huge Roman candles, sky rockets, toy pistols and boxes of caps. In the evening each doorstep had its separate and competitively brilliant display. This year, shut off in a colored community, there was not even a firecracker for sale.

Lee began to think of what could be done. They would have to make their own firecrackers. For Roman candles he took short lengths of elderberry stem, removed the pith, and filled the empty space with alternate wads of cotton saturated with kerosene and gunpowder. On the night of the Fourth he endangered his eyes in more or less futile attempts to shoot off these home-made pyrotechnics. Yells of joy resulted whenever one of the dimly illuminated cotton balls soared heavenward to the height of three feet.

The Southerners of that period had the strange custom of celebrating the Birth of Christ with fireworks. It was not done on the Fourth. Now and then ladies riding by behind their horses would glance curiously at the mad display behind the deForest house, or little girls and boys lean out and watch eagerly. But these were people whom none of the deForest family could ever hope to know. The deForests were outcasts, associates of Negroes. They let the fine folk stare.

No children in any period in history could ever have been thrown more completely upon their own resources than were the little playfellows in that backward community. In all the years of deForest's childhood, before the habits of thought that led him directly into invention had developed, when his mind was a nebula of pictures and feelings, there was but one high light.

One dreary afternoon his father came to take him for a walk. There was an attitude about father that

suggested a definite destination, but he did not trouble to tell the boy where he was going. Up several flights of stairs in one of the three-story buildings of the "down town" section — it may have been the building that harbored the one newspaper in Talladega —a small crowd of people were gathered in a hall, watching a strange object, the strangest the child had ever seen. It was actually a small box-like machine to which an ear-drum was attached. On one side of it was a crank which a man kept turning round, as first one and then another of the wide-eyed spectators got his chance with the ear-drum. As the ear-drum would pass from one to another the different faces would light up with astonishment.

When at last the man came around towards the minister and his son, the father held the drum to Lee's ear. As the man turned the crank a queer kind of voice spoke out. Lee was delirious with excitement. His father tried to calm him by explaining that the voice came from the machine — not from a man hidden somewhere in the room. The little machine was a replica of the first Edison tinfoil phonograph. Lee could not sleep that night for thinking about it, and his mother, hearing him tossing restlessly about in bed, brought him medicine for stomach trouble.

But the trouble went deeper than that. The phonograph had struck some chord in him that could not easily be silenced. She could not know, nor could he, that he would one day sit beside the great man who had made this marvel, and talk with him of the cities of the future.

III

In about his third year in Talladega, his daily existence set in a humdrum mold, Lee deForest began to develop another by-product of early childhood.

Talladega had its rainy season. Towards the end of winter came a succession of long gray endless days. Only one session in school in such weather. Home shortly after noon, Lee would go at once to the parlor and work on his toys, but sometimes the few odd nails and bits of wood he had managed to scrape together gave out. Then he would tire of toys that wouldn't go.

Time and again he would stand on the stairway and watch the great hands of the grandfather's clock, wondering desperately WHAT MADE IT TICK. The tick of this clock would consume his attention for hours. Upon one occasion he found that, by unlocking the glass door beneath its face, he could get hold of the heavy pendulum that swung back and forth as the ticks came out. The ticks stopped. He was breathless with excitement. When he let go of the pendulum the clock ticked again. So the swing of the pendulum regulated the ticks. He caught hold of it again and held it, in order to make sure of his discovery, but this time he held it too long. When at last he let go of it the clock stopped ticking

altogether. It had stopped. Lee fled up the steps in terror.

Several weeks passed before the pendulum swung again, and again the loud tick sounded. Again he crept up the stairs and watched the great black hands and wondered, painfully, what made it tick. What was inside? And again, although he felt he was committing a sin, he stealthily unlocked the glass door and caught hold of the pendulum. This venturing continued for a whole week before the clock stopped again, this time by treacherous hands that attempted to unfasten the pendulum from its moorings.

Again Lee would steal out of the house and wander down to a small structure next to Foster Hall, one of the buildings of Talladega College, where there was a printing shop with a hand-operated printing press. The mechanism of that printing press mystified him beyond words. Ink rollers ran down over the plates, inking the type. The method of spreading the ink over these rollers captured his curiosity. It became his ambition to become a printer, not from any literary urge, but because of the love of the intricate machinery involved in the printer's art. Then, he reasoned, he could try his hand at setting type.

One night the little printing shop caught fire and burned to the ground. Lee heard of it early the following morning, and a hard lump came up in his throat. Gone. . . . After breakfast he went down to the spot where the printing shop had stood. The ruins were still warm, burning still as he walked among them searching for fragments of the printing press that he might salvage. He burned his fingers and scorched his feet separating the remains of the press from the charred wood

of the shop, but the dirt and pain of the job meant nothing beside the fact that what he finally managed to get of the actual press was twisted woefully out of shape, and of no use even to him. Too desolate to return home, he went to wash his hands and face in Talladega Creek, and forget his troubles in a walk.

Machinery, the things that made other things go, that was his chief excitement. Whether it was a lawn mower moving up and down over the lawn, or the plough on two wheels — a recent importation, for heretofore the Negroes had been using hand ploughs — he would stand watching its movement for hours, pondering upon some possible improvement that would render its movement more facile, or accomplish greater results with less effort.

Another center of interest on those gray afternoons was the railway station. Although forbidden by his parents to go alone to the train tracks, he would nevertheless go out each afternoon at dusk and make his way to the station just before the daily arrival of the express on the East Tennessee, Virginia and Georgia Railroad. Down muddy streets, sometimes so soft underfoot that even knee-length boots were no protection, went this lonely little boy, keen-eyed, eager, starving for the sights and sounds of the outside world. Past the dingy collection of one and two-story houses arranged around the cobblestoned streets of the public square, past the gray bricks of the county courthouse, counting in his mind the boards in the wooden fence surrounding the square, "One . . . two . . . five . . . seven." On market days he would go out early, for then the square was crowded. To its four sides were hitched a heterogeneous assortment of ox teams, mules and

saddle horses, and past them Lee came at last within sight of the railway station.

He would plant himself at the very end of the platform, in order to get a full view of the locomotive as it steamed in and out of the station. The movement of the train, like the ticking of the clock, stirred in him an uneasy sense of wonderment.

That was the first question Lee deForest asked of the universe: *What makes it go?* What makes the engine move the train? If he could climb into the engineer's seat and move the heavy lever; crawl down under the monster and look up into its insides! Some time, somehow, he would do it. He vowed it solemnly to himself.

Meantime, he had to be satisfied that the narrow gauge road which had its terminal in Talladega ran close to some of the buildings of Talladega College, notably the building that held his own class room. This circumstance had permitted him to watch closely the construction of that road: the trestles across the branch, the deep cuts through the red iron clay, the lofty bridge rising mightily across Talladega Creek. In those early days he would have to hold himself to keep from running out to snatch a ride on the slow travelling caboose or passenger coach attached to the end of the narrow gauge freight train. It was hard to stay still. But in the evening, to see the locomotive close, close beside him, standing silently there in the station, then the longing to explore its every crevice, to touch it and hear it and feel it moving, that was actually painful.

In the very midst of his thirst came cool water.

His parents had gone to spend the summer with a

family called Witherby (to the modestly living deForests, wealthy and prosperous people) in a big old house at Shelby, Alabama. A week passed, a week of country picnics, visits to old Negro plantations and then Lee found that he could visit a wonderful place, a citadel of dreams called the Shelby Iron Works, and actually see blast furnaces, a foundry and machine shops! It was the most exciting thing that had ever happened to him. During the summer afternoons when the other children played contentedly on the lawn, he would run from the family circle and spend his time in the grounds of the iron works. There he would stand in open wonder and watch the casting of pig iron.

One of the workers told him that the tapping of the furnace took place three times a day during the twenty-four hours. After that, at the appointed time, he was there, waiting excitedly before the furnace. At night the spectacle was awesome. Then the flow of the molten iron which he saw through the opening at the mouth of the furnace had a fierce rhythm. It came down long narrow channels and into the pig molds on each side, like streams across a fiery ocean. Sweating dark men drew close, close to the mouth of the furnace, plugging the mass with long iron bars to make a larger float of the iron. These men had sweating black faces and overdeveloped black arms and hands. The child would wonder at the gentleness of their voices when they sang. But when they broke the slow cooling pigs loose from the main stem with gigantic hammers, the veins and sinews stood out under their bronze flesh like huge skeletons flashing into life and out again. They were fierce, savage. It was unforgettable.

During the whole of his stay at Shelby Lee lived for

these visits to the Iron Works. He learned all the details of pig iron making: the relative quantities of the iron ore, limestone, and coke that were dumped into the furnace; the operation of the gas ovens and air compressors; the length of the time required for a cast; how to draw off the slag on top of the iron; in a word, every step of the process from the rough iron ore to the flat cars laden with the pig iron. The summer days and nights, and all that they brought of outdoor fun, were like a childish dream beside the fierce heroic reality of a blast furnace!

One afternoon, on his way home from the Iron Works, Lee stopped off at the railroad tracks. There, on one of the side tracks, was a beautiful full-sized locomotive, deserted, a giant asleep. The very thing he wanted most in all the world: a chance to find out what made it go.

He climbed up to the engineer's cabin and tinkered with every object in sight: throttle, whistle cord, firebox. He even attempted to move the heavy reversing lever. If he succeeded, would the train go? He had never known how the mechanism for reversing a locomotive operated. Now he would find out. The sound of his own movements echoed in the silent train, but even the emptiness enchanted him. He had no fear, instead almost a hope, of the train moving on.

When he tired of toying with the throttle, pulling the whistle cord, and opening and peering into the firebox, he climbed down and crawled under the silent monster. This was the answer to a deep, sweet dream. He lay on his back on the wooden ties peering up at the bottom of the boiler, observing the intricate scheme

of eccentric rods, pistons, the slight valve rods. These he studied closely for a long time, observing their connecting links and making his decisions as to what function each performed. In his mind he could see the train in operation. The whole method of reversing the locomotive was clear at last.

Meantime it had grown dark. He could no longer see into the shadowy interior of the engine, but somehow he hated to get up. *Now* he had found out what made the locomotive go.

IV

No one is better able to interpret the wonder and the power of toys than the inventor, for inventions which change the aspect of civilization are first awkward toys upon which an isolated individual is hard at work. The story of the inventions and discoveries that have made possible this marvelous new world we live in is in substance man's childish longing for greater and greater toys.

The winter following Lee deForest's Shelby experience brought in new ideas to be expressed in new toys, a more exciting workshop in the long cold parlor, and outside the house, and found him a youth of thirteen years, grappling for the first time with intelligence, with the problem of how to make things go. The concentration that went into his work that winter marked a definite mental departure from the kind of life led by the other boys of Talladega.

Of course, he would have a locomotive of his own. With what care he selected a spot behind the house, beside a huge pile of wood. Behind this pile stood a small shed full of finely cut kindling wood, nicely stacked in symmetrically-arranged piles. He picked the spot beside the woodshed as the scene for the building

of a miniature of the mechanical wonder detailed in his mind since Shelby: a locomotive.

He made a careful inventory of the contents of the cellar. Barrels were selected for the boilers; a nail keg served as an excellent funnel; an empty biscuit tin was mounted in front of the keg as a headlight; a round hole cut in this and a small kerosene lamp for illumination. In the proper place underneath the front barrel he nailed keg heads for the small wheels of the locomotive. Another keg served as a cylinder, and a small wooden box on top of this as steam chest. A curved piece of hard wood ran from the steam chest into a hole drilled in the foremost of the three barrels which constituted the boiler. The purpose of this was to admit imaginary steam into steam chest and cylinder. The locomotive boiler consisted of three barrels set end to end and supported by two pieces of 2x4 timber. For tha cab he used a very large packing box that his brother and he dragged in with much pain and effort from the cellar. He labored with blistered hands to cut the necessary windows in this cab for the engineer. On its top he erected a small steam whistle made out of a tomato can. In the head of the barrel, within the cab, he cut the fire-box door. Above that he contrived a regulation locomotive throttle built chiefly of wooden parts, and held together by wire nails.

Then for the reversing lever. It did everything that a reversing lever in a real locomotive is designed to do. It shifted the eccentric rods and thereby actually produced displacement of the valve rods which ran into the "steam chest." For drive wheels he used two large barrel heads fastened to a box underneath the cab by means of large nails. A step also made of wood afforded

easy access for the engineer. Behind the locomotive they placed the tender complete in every detail, with water tank that leaked rather badly, being made entirely of wood, and a space for the accommodation of fuel for the locomotive. Because of the high price of coal this locomotive was a wood burner. Its tender was well stacked from the wood pile, although the funnel was designed for coal burning.

Nevertheless in spite of this slight inconsistency a single month saw a "life-sized" locomotive actually resting in the backyard of the deForest house, complete and finished in every detail. The children of the neighborhood, colored and white, came to look and marvel. How different was this locomotive from the awkward little block cars of five years ago. There it stood in all readiness to travel forward over non-existing rails into strange and untried lands. It was a success!

But the inspiration of his visit to the Shelby Blast Furnaces was not satisfied. Lee had another ambition: to build a furnace of his own. Unheard-of, impossible task! He found an old ash can and a lid, punched two holes in the can near the base, one for the admission of the nozzle of the compressed air supply, the other the tap hole from which the charge of molten iron was to emerge. As a source of compressed air he seized this opportunity to bring out from the upper fastnesses of the study closet where his father kept his old and treasured family heirlooms, a lovely old-fashioned bellows, relic of Colonial days.

Alongside of the blast furnace he constructed an elevator shaft for the purpose of hauling the fuel to the top of the furnace, with the iron ore and the pul-

verized limestone which was necessary as a flux. Then he built a chimney to his furnace. This, like the elevator shaft, was of pine wood, as indeed the observers who watched the furnace in operation for the first time could not fail to notice; for when the smoke from the furnace came through the chimney, the chimney itself took fire.

What detail that blast furnace possessed! He used for fuel in his furnace not coke but pitch-pine chips; his iron ore consisted of a lump of lead carefully placed on a brick of fire-clay laid in the bottom of the furnace, and so tilted that when the lead became molten it would flow down to the tap hole. In the sand in which the furnace was set, he had molded a runway to conduct the molten iron into two or three side-channels carefully stamped in the moist ground to represent the pig molds of a sure-enough furnace.

At length the hour arrived for firing the furnace. A lighted match was dropped into the mass of pitch-pine chips. The fuel lighted, the furnace lid was clamped on and the air compressor put hard to work. So earnestly did those two builders, Lee and Charley, pump the old family bellows, so hot became the furnace, so engrossed were they in repeated efforts to extinguish the flames from the pine wood chimney, that before they were aware of it the leather of the bellows had caught fire, and the Colonial relic became a charred sacrifice to the modern industrial era. But what did that matter in view of the grand triumph they experienced, when, after watching the chimney consume itself in flames, they punched away the wad of fire-clay which plugged the furnace tap hole and witnessed an actual flow of silvery lead down through the channel in the sand —

enough to fill at least half of the three pig molds which had been provided? The first Talladega blast furnace, although it cost the deForest family a valued heirloom, was a practical success.

These two strange toys standing in the yard behind the house began to attract a good deal of attention. Elegant ladies and gentlemen of Tallageda who held the deForests in supreme contempt, could be seen pulling in their steeds before the front lawn of the deForest house as they traversed Battle Street, asking permission to let their little girls and boys look at this new creation of those "damn Yank boys." Upon these occasions Lee and his brother Charley, smiling happily to themselves, would approach the fine black carriages and escort small groups of aloof well-dressed youngsters over the lawn to where the two toys stood behind the house. There the visitors would stand, wide-eyed, for they had seen life-sized locomotives only at the station, and the actual existence of a toy blast furnace was beyond their wildest dreams, while the two boys carefully explained how to work the locomotive, and, once in a long while, whenever there was a very large group present, let them see the blast furnace in operation.

Lee and Charles with their patched pants, stockings that did not always match, their grimy hands, their poverty, they had created these toys out of their own brain and with their own meager resources. They would smile cynically at the stupid questions put to them by the young swells, carefully tutored in their comfortable homes, and wealthy enough to send East for handsome manufactured playthings. There was a certain grim satisfaction in their own sense of superiority.

THE making of these two toys set up in Lee's mind a certain confidence that he could recreate the impressions and ideas gleaned from the outside world. He had at least the knowledge that the two paramount impressions of his Shelby visit had been successfully reproduced in miniature. But now there began again the impressionless life at Tallageda, with its streets of gray houses, its ox-teams, its courthouse, its locomotive, and its lessons at school, its Bible reading, prayers, and bed. Nevertheless he could read in books of the Knights of the Round Table, of medieval castles and the mystic rites of knighthood that had originated within the sacred confines of some mythical "Castle Luxembourg." And straightway he undertook the erection of a castle!

The walls of the castle were made of wooden slabs, and the cracks were covered by smaller strips. The floor was of pounded clay. One window was cut into the rear of the castle opposite the door. The structure was about six feet tall, its roof slanting to shed the rain, but on top stood a tall tower consisting of one barrel, carefully filled with stove fuel on the theory that if heavy enough the wind would not blow the tower down. A tall flag-pole penetrated the center of the tower and carried defiantly at its top a red pennant.

So began the "sacred confines" of the Castle Luxembourg. From its portals sallied at times large retinues of knights armed with long lances. What matter that the knights were sometimes darkies, that their lances were so long the castle could not contain them? The first circumstance was not deemed worthy of notice. For the second, a small window was cut in a front panel of the castle, through which the lances were projected

to rest. They were rendered safe, notwithstanding, by the promulgating of a "royal edict" by no less a hero than King Arthur himself, to the effect that all lances so protruding from the castle were inviolate from theft whether in time of peace or war.

The chief treasure which the castle enclosed rested in the body of the sacred altar, a wooden box which contained an ingeniously contrived breast-plate of tin, and gyves of the same material for the legs of King Arthur. The tin breast-plate and gyves were fastened by straps of cord. A tin sword, two feet long, with a wooden hilt, and a tin crown hammered out of a large herring can, completed the royal treasures.

There came one sacred vigil when brother Charley was initiated into the Circle of the Round Table. Then, a can of incense, consisting of flowers of sulphur, was lighted on the royal altar, Brother Charley placed on his knees in front of the altar, to remain in solitary vigil through the long hours of the night, the door and the single window of the castle carefully closed, and a furious attack launched at the castle from all sides. The attack consisted of a shower of brick-bats, stove wood, and bloodcurdling yells from other members of the Round Table knights as they surged upon the castle. Fortunately for Charley's continued existence, one of these missiles fractured the window shutter and thus prevented King Arthur's newly dubbed knight from becoming completely asphyxiated.

BOREDOM is one of the most potent incentives to creation. It is in part responsible for the brilliant fight

waged against the universe by those isolated individuals, the scientists.

It is often said that scientists are themselves dull people, "one cell men," interested only in the highly impersonal, peculiar world of their own. It is true. Undoubtedly, scientists seem to the layman unresponsive fellows. The scientist has made his escape from the personal world of human beings so long ago, has set up his house with the bricks of the universe so firmly, that it is difficult, well-nigh impossible, for him to turn back and take his place again in a world of loves, desires and hates. He would have to forsake his vision, forget the vast and beauteous picture that had lured him away from the world. And that he could never do. So he may fail in his personal life, and his lack of shrewdness in business is a commonplace, but no one can take from him the sights and sounds that only he can see and hear.

It was this boredom that made deForest turn and look with longing at anything that would go which was largely responsible for the need to create. And the toys he built then were the beginning of his creative life. He was starting then to inhabit a world different from that inhabited by the other children of Talladega. It is only now that one can estimate the uncanny significance of these difficult toys in his back yard. He was yet to learn how swiftly this tide of creation would sweep him up, and carry him along with it, or how far away from Talladega this surging tide would go.

V

The minute Lee deForest began to study elementary physics, school became interesting, but each year the downpour of rain that came to announce the end of winter so mutilated the roads that it was frequently impossible for the children to go to school. It was also impossible to work outside, and with the two points of interest, building toys and studying at school, completely cut off, it would seem that the days at home would have been dreary. But the sound of rain beating on the tin of the roof outside only made him eager to get up. He had a sweet exciting secret. He knew what to do on rainy days.

He would go into the parlor, raise high the window shades, and take down a large pasteboard box which had originally contained paper dress patterns. Here he had carefully stored the treasured drawings of his favorite inventions up to that time, Steam Hammers and Perpetual Motion Machines.

How this Steam Hammer fastened itself in his mind is still a mystery. He had never seen one in all his life, and all that he had read in the chapter on steam hammers in the encyclopedia merely described steam hammers and showed a picture of one or two. Possibly

what he had learned at Shelby regarding the mechanism of steam locomotion made this device and its detailed operation particularly interesting. Whatever the incentive, the steam hammer had taken the place in his mind of the locomotive image of former years. He had designed several types and sizes of steam hammers, and carefully worked out on paper the detail of the piston and steam valves for controlling the hammer.

But still closer to his heart lay a greater secret: *He had discovered Perpetual Motion!*

The very fact that the encyclopedia stated that perpetual motion was impossible, and illustrated numerous devices which had been tried by various enthusiasts from time immemorial, caught his fancy and challenged his inventiveness. His knowledge of the laws of physics, particularly of magnetism, was at this time so slight that he could not see *a priori* why perpetual motion was impossible. Hence it was possible! After long hours of deep thought, he designed and drew up sketches of a weird complicated device involving permanent magnets, walking beams, and magnetic shield devices. It was a wonderful machine. He delighted in it The most careful analysis of its operation convinced him beyond all doubt that he had succeeded where other inventors had failed.

The day he finished the drawing, he felt that he had at last solved the baffling mechanical problem of the universe. So great was his triumph that he appended at the bottom of the drawing a statement to the effect that he was actually amazed "that I, a mere youth of thirteen years, by my inventive genius and concentrated thought and study, have succeeded where illustrious philosophers in times past have failed, and have at last

furnished to humanity a machine which without cost will supply forever any and all demands of humanity for power!"

In his isolation there in the Talladega parlor, he felt in his heart that he *was,* not that he was to be, an inventor. The grandiose illusion of perpetual motion was only a part of his sense of his own destiny. It was not until some years later as a result of reading in physics and the laws of magnetism that he finally came to understand why his device was inoperative. On that unhappy day he burned up his drawing in shame at his own ignorance.

He had not learned that invention is itself a process of constant disillusionment, of tearing down and building anew, and that many an invention has been destroyed in a single blast by the bomb-like emergence of new facts into the world laboratory of science.

Lee deForest absorbed this sense of his own fate; it did not dawn suddenly upon him. Rather it asserted itself in his mind when that particular organ began to function. There was never a doubt in his mind, never a moment of wavering.

Whenever, in later years, he has been asked, "But what had the making of toys in Talladega to do with electricity?" he has only one answer: "Electricity makes things go. Behind even the crude wooden block cars moving down the length of that first Christmas, was a barely defined instinct to make a toy that would *go,* go out of Talladega, go far, far out into the world." The telegraph cables that today carry messages under the ocean from men and women separated by thousands

of miles; the telephone that brings a voice out of space into your waiting ears; the radio that brought the words of King George at the opening of the Naval parley from overseas to American firesides; the great power houses that flash light into your room, distill ice in your refrigerator — these are only the toys of men made to go by the strength of the giant, electricity.

He came to know this giant simply and naturally.

Talladega was at that time utterly devoid of anything electrical. Outside of the Western Union telegraph office, not even a wet-battery existed in the village. These facts Lee noticed, for he subscribed and eagerly read each weekly copy of the "Youth's Companion," and found somewhere in its pages a construction department illustrated with rudimentary diagrams and simple sketches of the most primitive kind of electrical and mechanical appliances which could be built at home by boys with a very modicum of tools and materials. To the modern boy all of this apparatus would appear much as the daguerreotypes of our grandmothers appear to the 1930 flapper: so do fashions change in motors. Today for a few cents a boy can buy ready-made a well-designed, beautifully running little motor for operation with a small battery. These are sold by hundreds of thousands in all our big cities. But nothing of this kind existed in the years of Lee deForest's boyhood.

He was compelled to build each and every motion-giving device with his own hands. One of the first crude motors he made by following the outline in the "Youth's Companion" was indeed the work of a pioneer. The armature consisted of a wooden spool with a nail stuck through the center. A more crude and im-

perfect type of motor could hardly have been designed, although the finished product represented days of hard labor. The boy working alone with the scant tools and materials in his cellar of long ago, working with his coils of wire and spools and nails and blocks of wood, makes a strange contrast to the fairylands of motors, toy automobiles and fire engines that litter the playrooms of today. The child of 1930 has only to press a button and an electrical universe, resounding with the whirr of toy Zeppelins and roar of electric trains, comes into being.

And in the summer of 1891 in a boys' camp in the North, he actually had an opportunity to study the rudiments of electrical engineering under an expert mechanic. With this tutelage he built toy motors which operated. The even movement of those motors is still one of the memorable events of his boyhood. This exciting work he carefully supplemented with deep reading in physics and mechanics and the science of electricity. All that summer long he was literally hypnotized with wonder at what he saw in actuality and in his mind. He pictured himself engaged in all kinds of engineering activities that would bring him in close touch with this miraculous giant electricity. He felt then that he would never quiet down until he knew all there was to know, came face to face with the giant and felt the full strength of his power.

He decided, upon returning home, this was the time to invent.

VI

The mechanical scrollsaw sent Lee deForest by an understanding uncle in the North was like a sword thrust suddenly into the hands of a hard-pressed warrior. He used it immediately in cutting out all sorts of devices: brackets, book shelves, small cabinets, and cupboards of all sizes and design. He became adept. All his spare pennies were spent for saw blades and wood, Spanish mahogany and holly, whose small stacks soon metamorphosed the upper hall of his father's house into a real workshop.

An idea fastened itself on Lee's mind: The entrance to some of the outlying parcels of land surrounding the college farm was through a type of gate which had long interested him. This gate could be opened either by the wheel of the incoming wagon, or by the driver on the seat without descending to the ground.

He set to work to design something that would be an improvement over the mechanical gates he had seen, working on a novel principle. Believing that he had a new design which possessed considerable merit, he undertook to demonstrate the truth or fallacy of his theory by an actual working model. He built a very pretty little miniature gate about three by eight inches, the

two long arms extending out into the roadway for the use of the driver, all in perfect proportion. This he mounted on a base of mahogany so that it would stand upright. The model operated efficiently. He varnished and made of it such a pretty toy that his mother set it up on a small table in the lower hall by way of an ornament.

This was the first working model that he had ever designed and actually built; in fact, his first practical invention. He felt that it had merit and ought to be protected by a patent, but the cost of a patent alone would have amounted to nearly forty dollars. It was unthinkable. Hence the little model stayed in the front hall, attracting from time to time the attention of visiting farmers, but so far as he knew no one became interested enough to construct an actual farm gate of this model type.

Disappointed, he turned his attention to bigger ideas, ideas that might make his parents understand once and for all that invention was his life's work, his destiny, not a means of passing the time. Since cotton growing was the main industry around Talladega, the sight of hundreds of sweating darkies slowly picking cotton by hand brought home the definite need of a cotton picking machine. Accordingly, Lee set his brain to work upon this difficult problem.

It occurred to him that cotton might be hand picked by means of stiff brushes, similar to hand brushes. Experiment followed. He gathered together as many different types of these brushes as the household afforded, carried them out into the cotton fields, and made some crude experiments in picking cotton by running these brushes across the cotton-bolls. The

brushes were effective. They picked the ripe cotton from the open hulls easily. But that was only half the process. How about the cotton accumulated in the brushes? How would he remove that? The problem continued to baffle him until he gave it up in despair.

All that he had done was to fill the brushes with cotton, much to the disgust of those members of his family who got hold of the brushes and found they had to clean out the thick tenacious cotton fibre. Altogether he was rather ashamed at the outcome of this bright idea.

But it did not stop him from constructing a marvelous self-propelled vehicle constructed entirely of wood, the only material he was able to handle competently. The front wheel, being the driver, was operated by means of levers, ratchets and pawls. By standing on the deck of this strange contraption and vigorously working the levers, he was able to propel himself across the lawn, or at least down the sloping part of the lawn.

Notwithstanding that it offered an outlet for his irrepressible zeal for invention and building, it was a weird and perfectly useless piece of machinery. And at last, when his father tired of seeing it around the yard, it contributed about one hundred pounds of excellent kindling wood to the kitchen fire.

Lee was depressed for a few days. Then he promptly forgot it. He began making some improvements on an intensely fascinating object, a "Chinese prayer machine." Some of his father's missionary friends just home from China visited at the deForest house and showed the children some queer prayer machines used by the Chinese in their devotions. The idea of having a machine for saying one's prayers appealed to Lee as a

delightfully practical means of dispensing with the dreary practice of offering the same prayer several times each day. The Chinese prayer machine was a small wooden object upon which a banner had been strung. Whenever the wind blew the banner, a prayer was believed to have been said.

Lee carefully sketched out several designs for the wind-driven prayer machines, greatly improving the Chinese method. He considered the idea of building one of his own, but here his courage failed and he hid the drawing for fear of having to offer a different kind of prayer, to his earthly father rather than to God.

By this time, the period of his Talladega inventions, he was sixteen years old and firmly set in the idea of what his future was to be. So obvious was his determination, so pronounced was his interest in scientific and mechanical matters, that it had at last become clear to his father that this "hobby" of Lee's might possibly cause trouble in starting the boy on the fast-approaching course of his life's work. Dr. deForest began to look askance at these "inventions" of Lee's and to discourage his fanatical interest in electricity. Lee knew there was a battle ahead and he wanted it to come soon.

VII

"WHY do you choose such a hard way?"

Dr. deForest is standing at the far end of the parlor, one of his strong rugged hands resting on the edge of a dusty cabinet. He looks strangely out of place among the objects of that room. There is a sharp division line between the lean, blue-eyed boy, eager for sights and sounds and movement, for hardship and for life, and the middle-aged minister of God looking down upon the peaceful aisles of the church towards his familiar pulpit.

It will soon be time to part company. The parlor has changed during these thirteen years in Talladega. From the first Christmas night when the awkward crazy little block cars refused to move across an empty floor, to a miniature universe of nineteenth century industrialism. Brought here by this boy alone. Reached for far out of Talladega, beyond its muddy streets. Created out of his own mind, it is the brightest spot in all the gray town.

The head of the pastor stands out sharply against strange mechanical devices, some of them still in the making. It is a complete and compact little world. Elementary books on physics, mechanics and electricity,

some five in all, are stocked carefully in a well-built bookcase made with the scrollsaw. In the midst of it all stands a boy of seventeen. Keen-eyed, energetic, eager, scared of the outside world. Still he wants to go on now and make a greater world. . . .

"But why do you choose such a hard way?"

Those words came in at last — the end of the battle, voicing the father's last frail hope of redeeming his son. They have travelled with the boy, come in upon him many a time when, torn away from his work, beaten about on all sides by poverty and by ignorance, he has asked himself, "Why indeed have I chosen such a hard way? For no harder way is there in all the world. *What* made me an inventor? Why couldn't I turn back, there in the familiar town of my childhood, even though my mind had strayed, and follow my dear father into the shady recesses of the church? Why couldn't I sing the hymns? say the prayers? believe the Word? What makes me go out into the frozen corners of the earth and delight in breaking its ice? *Why?* Why have I chosen the hardest way?"

And the answer he has made to himself down through the years has been the same as that answer he made to his father at seventeen. A romantic answer, the answer of a boy, it is still the answer of the great man of today.

"This is what I *must* do. It is my destiny."

DURING his last few years in Talladega, Lee's interest in mechanics and invention had begun to crowd out everything else. He had made up his mind in private that he would enter the Scientific School at Yale, al-

though he knew his father had set his heart upon having him study the Yale classical course from which he himself graduated in the class of '57, and so become a minister. But Greek and Latin were anathema to Lee. He studied the eclogues of Virgil and bore with the onerous difficulties of mastering Latin conjugations and syntax, only because he realized he would have to pass a Latin examination to enter the scientific school. Greek bored and horrified him. His father forced him to study it for one year, and he gave in to his father's wish under violent protest. Face to face with the Greek alphabet, he found that the only interest he had in it was the fact that certain advanced mathematical treatises which he hoped one day to study were full of Greek symbols.

"This is wasting time," he had elaborately explained to his father. "My only possible interest in either of these dead languages is its connection with science, and that connection isn't strong enough to carry me through."

In time, realizing the importance of explaining his point of view once and for all, he wrote his father a letter. It is dated October 4, 1890.

"Dear Sir," it reads, "will you favor me with your ears for a few moments? I want to state my desires and purposes. I intend to be a machinist and inventor, because I have great talent in that direction. In this I think you will agree with me. Now then, why not allow me to so study as to best prepare myself for that profession? To this end it would be much better to prepare myself for, and take the Sheffield Scientific Course than the Yale University Course. Besides, I could prepare for it in one more year, and the cost would be much

less. This, my dear sir, would be a great item with you who have us all to educate. The time and money it would take to let me study both courses could thus be spared, because a great deal of what I would learn in the university would be of no advantage to one of my profession, whereas what I would learn in the scientific course would be of the greatest use. I think you will agree with me about this, on reflection, and earnestly hope you will accordingly educate me for my profession. I write this with no ill will in the least but believing it is time to decide, and choose my studies accordingly."

On the other side of this letter he had carefully typed a note for his mother. It began with:

"Lives of great men all remind us
We can make our lives sublime,
And departing leave behind us
Footprints on the sands of time.

"Footprints that perhaps another
Traveling o'er life's desert plain,
A forlorn and shipwrecked brother,
Seeing, may take heart again."

"Dear Mamma," the note read, "the only footprints I will leave will be my inventions. I had better take the scientific course, don't you think so?"

The letter was sticking out of his father's pocket when he entered the parlor that far-off day, and sat down on the one armchair in the room. He had come to talk of the future, he said. And, strangely enough, he began to talk of the past: the stream of people who stood behind this boy, ancestors, and the great work

they had done in the service of God. He went eight generations back to the beginning of the 17th century, when a man named Jesse deForest, a Huguenot refugee from Flanders, who during religious persecution had organized a band of French Walloons, obtained a charter from the King of England, and led his colony to British Guiana. His eldest son, Isaac deForest, following in the footsteps of his adventurous father, organized another group, sailed up to the mouth of what is now the Hudson River, and settled in New Amsterdam. From these pioneering descendants, Henry Swift deForest earnestly explained to his son Lee, all the deForests in America originated.

"Why shouldn't you be proud to follow in their footsteps?"

Lee answered that it was impossible. Why? Didn't he believe in God? Yes, he did believe, and in all the holy tenets of the church, but he could never keep his mind upon them. He too wanted to explore, but in science. He would not teach others or preach. Quietly he stood beside the long parlor window, glancing from time to time at the thick muddy streets without, sensing that he was hurting his father, awkward with words.

"Do you think because you've put a few blocks of wood together that you can invent?"

He couldn't explain, or answer. It was too close to him. He wanted to guard and cherish it, this idea of what he would do and be, to hide it, if need be, anything to stave off laughter. Besides, how could he explain that the scrollsaw was his altar, this workshop, his church, science his religion? That his heart beat wildly on reading a book on physics, but the droning of prayers put him to sleep?

"Where did you get this idea anyway?"

Nothing to say here. He didn't know. Nothing to suggest an inventor would ever exist in his family. His father came down to more practical matters.

"How will you ever go about it? You'll have to work even to send yourself through college. How will you live after you leave college, much less buy materials?"

"I'll live, I'll manage."

"And how will you ever find out anything about electricity? It isn't yet an exact science. Nobody knows very much about it. You can't even take a course in electricity in any college."

This he knew. His father's earnest face grew solemn as he continued.

"These ideas of yours may go up in smoke — like your cotton-picking machine, and the contraption I finally had to burn. But then it will be too late, my son, too late to study a sensible profession."

He waited for Lee's answer.

"I cannot study the classics, Papa. I am interested in science, and its natural expression, mechanics and invention. I have known about it as far back as I can remember. It is . . ." (Lee was going to say his religion) "my destiny."

The Reverend shook his head, resignedly. His anger and disappointment must have turned to pity when he asked, "Why do you choose such a hard way?"

But the boy shrugged his shoulders. He did not know how hard it was, nor did he care, because then all hardships looked to him a part of the pain and glitter of his own faith. Besides he was waiting for his father to say to what school he could go, so that he might

know how soon he would leave. He knew that the elder had given up now.

"Very well. Go your own way."

The father went quietly out of the room, shutting the parlor door carefully behind him, as if to close off the sight of his son's future, leaving the boy standing there filled with the strange objects he had made and with the ideas that would soon lead him beyond the railroad station.

VIII

They rode through the town.

It was market day in Talladega. All day long, while Lee deForest carefully packed his books and his sketches in a big wooden box, the ox carts had been rolling over the cobblestones in Battle Street, bringing in the farmers and their produce for market day. It was a warm droning summery day, a day suggesting dreams and sleep, but all day long a deep moving excitement had kept him hard at work in the parlor. It was his last day in Talladega. The boxes were packed at last and expressed to Moody's School for Boys, Mt. Hermon, Mass., the agreed stopping-off place between Talladega and Yale, between the small town and the great world.

At five o'clock his father had come for him — his mother was to bring his brother Charley and his sister Mary to the station, from the market place — and silently the father and son rode together in the weather-marked, one-horse buggy, down through the streets of Talladega.

It was Lee deForest's last sight of the town, and now he noticed it closely. Down through its streets industry had moved at last. In place of the vile mud that only a

short time ago had made all transportation difficult were even rows of white cobblestones with blue grass and dandelions springing up between them. The water in the gutters, now bright green with slippery summer moss, ran down a lower level to a covered sewer, instead of to an open pipe stuck in the ground. Woodwork on the houses was as gingerbready as usual, but further down the street, in the public square, were a few new three- and four-story brick buildings, simply built and strong. Above all, symbol of change, two great arc lamps were hung on high poles in the market place, casting an eerie purple glow over the streets and houses.

Father and son were silent. Only a few days before his leavetaking the father had prophesied that the "toys and contraptions" of his young son would win for him ridicule rather than renown, that his ideas would "fade out in the light of a few years," and that he would come back to Talladega. Silence had followed. It continued now as they rode together through the town — Lee too elated for speech, his father too sad.

Down familiar streets, past the two brick-paved blocks where the dull-eyed oxen and horses moved slowly. Through these streets they rode swiftly, the sound of the buggy wheels assaulting the peace of Talladega. Past the creek with its great bridge, down the road to the farmlands in which, though rich with growing things, was sweat and monotony. Poverty and weariness, part of it went with the boy out into the world. He was hit deep with poverty, and he knew it. As he thought, his faith went dark in its shadow. It was comfortable in the deForest home in Talladega; comfortable in the churches, in the yard, in the sun. Not much expected of anyone, food to eat and a bed at

night. On *his* way there would not even be that. Pictures came crowding in before him there in the dust of the road. Suppose — suppose he was wrong. . . .

Suddenly an object in the landscape caught and held his attention: a farm gate, different from the other farm gates these two had been passing, with two long arms protruding out into the roadway. Lee caught his father's arm nervously and jumped down.

"Why, it's just like my little model!"

It was, complete in every detail. The father nodded, indifferently.

"I'm going to ask Farmer Levitt where he got it."

"You haven't got time. We're already late."

He felt that his father was evading, but soon Dr. deForest's honesty asserted itself.

"I'll tell you about it," he called to the boy. "Get back in."

Lee hated to leave this life-sized copy of his own idea, but he climbed up into the seat.

"Farmer Levitt saw your toy gate in the hall and asked us if he could borrow it. I think he had it copied somewhere in town — he told me he might do that. It would cost him less than sending away for a manufactured gate."

The dust came up again as they rode on. No thanks, no credit, not even a word of praise; but there was his gate swinging out into the roadway, proving its own merit and proving Lee deForest to himself.

They drove faster. Gray dust and brown, rusty leaves dropping in the silent day. The road went on to the railway station, and the rails of the train went far, far out in the world.

PART TWO

HERR HERTZ'S WAVES

I

THE locomotive that steamed out of Talladega — away from ox-teams and cobblestones — did not bring the hungry young inventor to a great city where he could feast upon sights and sounds. It brought him instead to a crude agricultural preparatory school dominated by two ideas: development of the physical body for life in this world; close attention to dogmatic religion in preparation for life in the hereafter. But Lee deForest was starving for new impressions, knowledge, training; and here these were secondary. Farm work and Bible study were the two great divisions of labor at Mt. Hermon.

At night the friendless boy from Talladega would go to a long narrow slice of room, the plainest room he had ever seen, stretch wearily in his bed and watch the big round head of a boy in the next bed, or gaze out of the single window to the deep dark pine woods that lay beyond the school. "Only two years," he would whisper to himself. "Only two years — and I'll be on. . . ."

Like many another creative spirit, he had begun to keep a diary. In the section devoted to his two years at Mt. Hermon he made almost no note of the fact that

he was actually doing three years' work in two. He liked heavy courses in higher algebra, geometry and trigonometry, plane and spherical, and in addition Latin, chemistry, physics, music, moral philosophy. He hardly noticed that he was poor, lonely, friendless. Instead, his quarrel with Mt. Hermon was almost entirely against the "senseless hardship of farm work" which left him too weary for mental agility in his studies. This farm work was an "obstacle" in the way of his tireless ambitions. He alone of all the students resented the rawness of the superintendents who each afternoon bawled them into a despairing kind of obedience. And he consistently put up a fight against the long hard hours of stupid drudgery that finally won him a short-lived immunity.

It was not until his senior year, in the cheerful new science hall which had just been completed, that de-Forest found himself inside a laboratory doing actual experimental work, and into his blood there stole again the sense of power he had felt in his poor workshop in Talladega: "the sense of being in the right place doing the right thing," he called it in his diary. It was not so bad then. Each day brought new adventures in the realm of chemistry and physics; each day unfolded some fundamental of electricity; how to solve problems of installations, how to operate incandescent lamps, dynamos, motors. Even though he could not see the instruments he longed to see — galvanometers, meters, the common equipment of any high school of today; though his work was limited almost entirely to reading and solving on paper problems presented, still he felt himself somehow closer to that outside world, the world of ideas and of machines, that he was nearing all

too slowly. It was from an interesting teacher, Professor Dickerson, alone that he received a training in physics and chemistry which had a most profound and lasting influence in forming his mental character and in framing his career. Dickerson was young, enthusiastic, interested in his students. He presented his subjects in the most colorful manner. DeForest was careful not to miss a word of the invaluable information he was receiving, information which swiftly became organized in his mind and which has remained to this day a steady inspiration.

In the summer of 1893 he graduated with high honors from Mt. Hermon Preparatory School, went down to Yale literally bursting with knowledge and passed the entrance examinations with flying colors. He was twenty years old then, a thin shabby youth with dark hair and piercing tense blue eyes. He had only the fare to New Haven and a few dollars that would have to buy a great many meals throughout the weeks of summer. He looked poor indeed in his coarse shirt and shiny suit, a straw hat inherited from his father the preceding summer, and shoes one year old, by contrast to the well-dressed young men who came to take the entrance examinations. He was awkward, too, graceless in his contacts with people, always saying the wrong thing at the wrong time and withdrawing to stand and wonder just what he had done this time. To watch him walking alone in contrast to the comfortable, gay youths who flocked in twos and threes down the streets of the City of Elms one might indeed have concluded that here was a man with a limited future, an individual locked within himself, with no charm and with no worldly advantages save his pressing, almost fanatic

ambitions. Where indeed was he going? And how would he go about getting there?

It is still summer but the scene is very different from that of the stately City of the Elms. This is White City at Chicago with courts and galleries, golden domes, gondolas speeding over blue waters, and telephones, telegraphs, electric transportation. A strange city for 1893.

Down the streets boys in uniform are pushing men and women in comfortable wheel chairs. One of the men, an irate farmer, is arguing with his chair-pusher.

"This ain't the way to the House of All Nations."

The chair-pusher does not answer.

"I want to see the hula-hula dancer," the farmer complains.

"Let's go first to Machinery Hall," the uniform suggests, "I want to show you something wonderful. Besides, we're almost there."

He turns the chair swiftly to the left. He is too excited at the prospect of what lies beyond the white palace of steel and glass to argue intelligently with the man from the grass-roots.

"Come in just once," the young man pleads, "then we will go to the House of All Nations."

Dully the farmer lets himself be persuaded. He is dreaming of the hula-hula dancer whose fabled wonders he is soon to see. The young chair-pusher, one Lee de-Forest, looks, too, like a man who has seen a vision. But it is a very different vision from that of the Iowa farmer. He has seen the curtain rise upon the spectacle of electricity at that great drama of the century, the

World's Fair. And although he is performing a coolie's task as primitive as the water-wheel, his head is filled with problems of high-speed transportation, and the exciting prospect of the swift transmission of intelligence.

He has looked into the face of his world for the first time, examined its life-sized stature, marveled at its vastness. He knows just where to find the railway exhibit that contains the famous New York Central locomotive 999, which drew the "Exposition Flyer" from New York to Chicago. To the sight-seers it is only a train but the beauty and power of it thrills the chair-pusher like a symphony of music. He knows just where to find the most modern type-setting machinery, presses which turn out their ninety thousand per hour, folding machines of the most recent delicate and complicated pattern. He has examined carefully the works of all the great electrical establishments which have sprung up in the ten years he has been dreaming of them; the cars flying over elevated roads with no visible means of locomotion; the "haunted corners" where astonished people talk to friends almost a hundred miles away and actually hear their voices.

Small wonder that young Lee deForest returns whenever he can to Machinery Hall, for here he got his very first contact with the broader world of affairs which was absorbing the talents and energies of a whole new generation of American inventors and engineers. The process of what has been called the "Invention of Inventions" had its inception there. It was indeed the beginning of a new era, for out of these houses of wonder there emerged inventive America at its full stature. And the sense of his own destiny, of what perhaps was

to be his contribution to this panorama of power, added brilliance and greatness to all deForest saw.

The irate farmer found himself gazing at the workings of a steam hammer — conveyed thither by the impetuous chair-pusher who explained to the bewildered rustic the marvels he was unwillingly beholding.

What these sights meant to Lee deForest is best described in his own words, written in his diary under the heading "World's Fair in Chicago — 1893."

"Fortunately for me, the Amalgamated Order of Chair-Pushers has gone on strike in the fair grounds, and the company in charge of the grounds advertised for strike-breakers. Although it's against my principles to side against rather than *for* the poor men who push the chairs, I took a job as chair-pusher yesterday because the idea of leaving the fair grounds is like the idea of leaving heaven. The salary is small and my uniform cost eight dollars, but it means staying longer in this city of dreams.

"I spend every spare moment in Machinery Hall, seeing the same electrical exhibits, the same machines, time and time again. Whenever the huge steam hammer operates before my eyes I am intrigued anew. It seems to tower mountain high. Even in Talladega, touching the picture in Papa's encyclopaedia, I did not dream a steam hammer was nearly so big. The guide books spare not a single word to illustrate the vastness of this project. They tell to a cartload how many tons of materials are used, how many acres of glass give light to the whole, how many acres of ground are covered, yet these figures by themselves convey no impression of vastness by contrast to that deep impression which is even now towering in my mind.

"The whole electrical service at the exposition comprises two systems: arc lighting, incandescent lighting, and electric power — in the form of telephone service, police signal service, fire alarm service, telegraph service, and electric transportation.

"The most exciting electrical feature, because it is new, is the use of electricity for the transmission of power. An immense array of motors. I shall never forget."

II

But this was a city of the future, a creation of the magic of men's imagination, while New Haven was a city of the present. A difficult present, even though it represented to Lee deForest his very first contact with civilized life. Actual college life that usually presupposes standardization, a sudden entrance from wide fields into a closed-in territory, a lessening in the color and contrasts of the individual, meant to him the first opportunity for giving form and meaning to the chaos of his mind.

He noticed at once the vast difference between the magic city in Chicago and this city of New Haven that was to be his home. There was age and dignity in the trees, the parks, the avenues, the college buildings — and little else. The streets were lighted by arc lamps. Now and then, walking in the very wealthy residential district, a promenader might notice a shaft of bright light across the smooth lawns: the people within were able to afford the spectacle of electric lighting. Kerosene lamps were the source of illumination in many of the students' rooms at Yale; gas mantles and kerosene lamps in the houses of the city. And as for the "intramural electric railway," equipped to handle 16,000 passengers

in one hour, with its block signal system, the "device that stopped the current and set the brake on the train in case the motorman ran past a danger signal, an almost super-human intelligence," that was part of a far-away world.

There was not even a trolley car in New Haven. Horse-drawn cars, with plenty of straw on the bottom to keep your feet warm in cold weather, took the large crowd of students and their girl companions out to Lake Whitney for ice skating. The college rooms were none too well heated by single hot-air radiators in one corner. Only the very rich had anything better to bathe in than tin bathtubs with brass faucets. The paint was usually in a disintegrating condition in the bottom of the bathtub and even though the students used scrubbers or stiff bristle brooms it was always a question as to whether they would emerge cleaner than when they went in.

Looking down the avenues and into the houses of New Haven, Lee deForest began to wonder anew at the majesty of this frozen dream he had seen at Chicago, a mystic city as different from any city that actually existed as was the town of Talladega with its dim arc lights casting their eerie purple glow over the cobblestones of the street below from the great, lighted thoroughfares of the future.

But if the giant, electricity, seemed far removed from the ordinary routine of deForest's daily physical existence at Sheffield it was still further removed from the ordinary mental routine. The freshman term found him studying analytical geometry, German, mechanical drafting, physics, English and chemistry. Physics, a course in which the professor frequently demonstrated apparatus and instruments before the class, caught and

held him. Study in electricity was limited to applications in the field of electric lighting, electro-plating and electric motors. Wireless was not yet dreamed of. It seemed indeed so very remote that deForest's restless attention turned to psychology and metaphysics for its outlet.

Laboratory equipment at Sheffield in that day was meagre and insufficient beyond description. In the basement of North Sheffield there was a large storage battery, a small dynamo, a few standards of capacity and inductance, several types of galvanometers. This equipment constituted the "electrical" laboratory. As a matter of fact the course in Electrical Engineering was nothing more than an experimental offshoot of the course in Mechanical Engineering, a fragmentary study. What, then, was Lee to do with his inventive genius?

Without any shop or laboratory where he could put designs into physical form, he nevertheless set about expressing some of the ideas that had haunted him since his sight of the World's Fair. He first designed a game intended to compete with "Pigs in Clover," a miniature of the various buildings and museums on either side of the Midway Plaisance at Chicago, with entrances cut into these tiny buildings. Two pedestrians were represented by two lead shots: a large one representing a fat lady, the smaller one her husband. The entrance to the House of All Nations was made particularly easy of entrance for the small shot, but very difficult for the large one. One of the features of the puzzle — it is obvious that this was a puzzle which the young man believed he might sell and so alleviate the pain of his poverty — was to get the small shot past the entrance to the House of All Nations without going in, and to get the large one through the portals. His

simple little working model of cardboard, wood, glass and gum paper went out to a well-known toy manufacturer — and apparently stayed there. Nothing came of it.

But the invention upon which he staked his hopes was created to win a prize competition of fifty thousand dollars offered by the New York Street Railway Company which was at that time contemplating replacing the Broadway cable by an underground trolley. DeForest heard of the offer through the "Scientific American," and immediately worked out some elaborate plans for what he considered a practical construction of an underground trolley which would be free from serious current leakage losses due to slush, water or mud getting through the slot in the surface of the street into the conduit below. The principle was to have the live conductor completely enclosed in a flexible rubber shoe or boot and to have short sections of copper riveted to the lower side of this boot in such a way as not to interfere with the flexibility of the covering. Then, piece by piece, as the trolley shoe progressed, the sectional conductor was to be forced up into contact with the live conductor or rail, falling away again out of contact therefrom as fast as the trolley shoe traveled further and made contact with the next section of the secondary conductor.

The very best comment upon this invention is by deForest himself in his diary. He wrote,

"The method I had planned would have been an expensive one to install and maintain, yet it undoubtedly possessed the secondary advantage of keeping the conductor entirely insulated from external objects except at the spots where the trolley car shoes happened to be located. I did not know how much serious con-

sideration my plans and drawings, over which I had labored so laboriously, had received from the 'Scientific American' commission appointed to pass on the various plans which were submitted. Suffice it to say that in due time my drawings were returned to me with a polite but terse statement that the commission had found them unavailable. So another pet dream was shattered."

All of his inventions at Yale were failures. The resulting reaction on the young inventor was not so much one of disappointment as it was a sense of being blocked in, cut off from contact with the world of achievement in which even a failure was dignified. He began to feed his imagination upon all the news he could obtain of the outside world, to devour all the literature he could find on the lives of the inventors, and to follow the satisfying conquests of the giant electricity. Intensive reading and study late at night in his narrow low-ceilinged bedroom, the ordinary escape from reality of older men, early became a refuge of this imaginative young student. What though his experiments were unsatisfactory, what though the information he carefully stored each day was largely theoretical — each night he could send his far-reaching vision out into the world, there to dwell until reality should at last return to him. Books, clippings from newspapers, magazine articles, these gathered together upon the small table near his bed built up an entire world in which to live and move and have his being.

In his senior year at Yale things began to happen to Lee deForest. The curtain had risen upon the spectacle of electricity at the World's Fair in Chicago, but the

drama did not begin until the year before graduation. Then he began to understand the part that Michael Faraday had played in the discovery of electrical principles, the relation between electricity and magnetism. Higher mathematics explained to deForest the accepted theory of the first essential, that is, the medium that transmits electrical effects through space. He began to follow closely the reasoning of James Clerk Maxwell, who was primarily a mathematician working on paper with symbols and formulas, and to understand something of Maxwell's profound mathematical study of the way in which light flashes through space. He read carefully every word of Maxwell's classic book "Electricity and Magnetism" and came to understand what was meant by electrical wave motion, or electromagnetic waves. The idea that these waves had actually been rendered visible seemed to deForest the most fascinating thing he had ever heard of. His understanding of Maxwell's theory had already excited and astonished him. Now Heinrich Hertz, whose classic experiments had confirmed Maxwell's theory, became Lee's new hero. His diary is filled with descriptions of what he called "Hertz's simple experiment."

"What Hertz actually did in 1887 was simply to create electric sparks in his laboratory at the opposite end of which was mounted a 'resonator,' that is, a metal ring not completely closed, and therefore provided with a little gap. When sparks crackled in the sending apparatus, tiny answering sparks could be seen in the gap in the ring. I see it all in my mind very clearly, but I cannot say that I understand it."

Just as this question was becoming pressing, Professor Bunstead of Yale delivered what was to deForest

an epochal lecture on Herr Hertz's electric waves. DeForest was seated in the front row. The words that fell from the lips of the professor were indeed oracular. In them lay the young man's destiny. He learned then and there in what manner Hertz's waves were actually discovered and — *saw them created before his eyes.* The apparatus which Professor Bunstead had constructed for reflecting the Hertzian waves was indeed an object of wonder to the students. They gazed, and were silent.

DeForest himself was too excited to sleep. All night long he lay awake, pondering the wonder of what he had seen, the brilliant new world that had beckoned to him. For weeks after this lecture he was too tense to attend to his ordinary studies or even to sleep soundly. But he knew that he had found himself, found an entirely new and unlimited field for study, research, and a life career.

III

In his senior year at Yale, Lee deForest branched off into a realm then inhabited by only a few isolated individuals the world over, a planet that existed apart from the planet of ordinary mortals and that was habitable for only a few. But the true significance of how he got there and what he did when he did arrive can hardly be explained without a closer glimpse into the recesses of his mind.

What instinct, apart from his natural talents and inclinations, led this young man to choose the strange field of wireless for his life's work? Why should it have been deForest rather than the hundreds of other young men?

One answer doubtless lies in the fact that Lee deForest was one who fought inward battles day by day, night by night, while his college mates indulged in athletics or in girls. Throughout his college days, for instance, his conscience, inherited from his Christian training, arose at every step of the way and turned from what was interesting and exciting to what was moral, dutiful and upright. This quality, sadly enough, had built up a great wall about the lad. He made few real friends, although he had a lighter side, yet so long and so inevitable seemed his isolation that he resigned him-

self to it. He went daily closer and closer, deeper and deeper into himself, fighting his interminable if painful battle for knowledge, satiating his spiritual cravings, even though his flesh was denied.

This introversion was made doubly hard to sustain because, while it was a by-product of his religious training, his faith had begun to fail him. He did not know that he had already embarked upon one of the most interesting phases in the development of the scientific mind: the gradual decay of its old beliefs. The process of doubting the God of his early religion had begun and continued until it drove him on as a lonely human being left bare of props, of consolation, almost of hope. Then he turned forward because he saw he could never go backwards.

It was a hard road. Today, in this age of scientific skepticism, deForest would have shed his religion easily enough. Since, however, his oncoming observation was so thoroughly opposed to his early training, the latter quite naturally slowly gave way. He discovered Spencer and Huxley. Naturally their logic sounded much better than the allegorical tales of Creation that he had learned to believe, as it were without thinking, from long years past. He stumbled upon evolution and Darwin. He abandoned the Jehovah of the Bible. Immediately after this he felt happier, just as he had felt in those days long past at the Shelby Iron Works when he had at last found out to his satisfaction how the locomotive worked.

"It is ignorance that makes us old," he wrote in his diary. "I am young again, for I have lifted a great load from my mind."

DeForest began to wonder where he would turn for

sustenance. Life was already hard for the young inventor, as it must inevitably be for those who combine intense ambition with stark poverty. Where would he turn now for his anodyne? For that sweet whisper of consolation that only yesterday had seemed to come from the skies? "This new position is painful," he was moved to write in his diaries. "At times I feel hopeless and would like to regain the easier, more comfortable thoughts of my childhood. I wish indeed that I could not feel this indistinguishable flame of truth burning in me that drives me on — on — no matter how much it hurts — no matter where."

So the young man in his last years at Yale. Poverty on one side, insufficiently nourishing meals at Jackson's restaurant, for his meals must not average more than fifteen or twenty cents. For that sum of money he tried to satisfy the pangs of hunger that gnawed at him while he attempted to study. On the other hand, an inward battle waged in such silence, isolation. In the midst of it, he woke up one night with a terrific fever. Typhoid. For three long weeks he lay in bed in the Yale Infirmary. An underfed body and an over-active brain had brought the illness upon him. The doctor warned him that after this he dared not limit himself to milk toast. There must be an occasional beefsteak, if he was to keep body and mind together.

Immediately after his illness, weak in body, still questioning the universe, he stumbled upon the poem:

> "Out of the dark that covers me,
> Black as the night from pole to pole,
> I thank whatever gods there be
> For my unconquerable soul."

He read carefully the four verses. especially those last two lines:

"I am the captain of my fate.
I am the master of my soul."

A strange elation possessed him. Yes, yes, this was his poem, written for him to find. A bright light streamed in from the windows of the library, flooding the polished tops of the long tables in small brilliant pools, touching the bent heads of the youths still at their studies. He sat quite still until the bell rang, and even then he was loath to go away. He wanted to remember the faces about him there in the library, the shadows and the poem. This minute was an epoch. He had found his answer. Now he would throw himself into work and cease all contemplation. Now he would act.

IV

It was a warm summer day late in June, 1896. New Haven hummed with the sound of insects and the gentle rustle of leaves. Commencement was just over, the last of the stragglers had just seen their trunks and baggage hauled off to the station in the town's disreputable express vans, and the stragglers themselves stood about while they prolonged their good-byes until train time. Suddenly the streets of New Haven were filled with cheers and farewells. Coaches drew up and disappeared. The young men had gone on into the future. But Lee was to remain in New Haven for post-graduate work in electrical engineering. This was made possible by the devotion of his mother who left Talladega after the sudden and tragic death of Lee's father and came on to New Haven during her son's senior year at Yale. She kept a rooming house on "Freshman Row" on Temple Street, for five years, to enable Lee to continue his post-graduate work, and that Charles could also go through Yale and graduate in 1901.

Lee stood at his window thinking of the marvelous experiments that were going on in Europe. The modest German professor at the University of Bonn, Heinrich Hertz, had years before invented an "eye" to see the

invisible electro-magnetic waves. In laboratories over the world scientists were beginning to study these newly discovered "Hertzian waves." New "eyes" to see them were invented, "eyes" far more delicate and far-seeing than Hertz's original simple open metal ring or resonator. In Russia, Popoff had begun to study the waves in lightning. Lodge, in England, and Branly, in France, were also performing notable experiments to acquaint mankind with the nature of the waves, for in these waves existed a new and astonishing world.

In 1896, the year in which young deForest sat looking into "space," electric waves had been sent out into the ether and "seen" by special "eyes" or detectors. The idea of utilizing these waves to send and receive intelligence had first occurred to Sir William Crookes in 1892. DeForest had read every word of Crookes' article on "Some Possibilities in Electricity" published in the "Fortnightly Review." He well remembered Crookes' prophetic words:

"What remains to be discovered is—firstly, a simpler and more certain means of generating electrical waves of any desired wave-length, from the shortest, say a few feet in length, which will easily pass through buildings and fogs, to those long waves whose lengths are measured by tens, hundreds, and thousand of miles; secondly, more delicate receivers which will respond to wave-lengths between certain defined limits and be silent to all others; thirdly, means of darting the sheaf of rays in any desired direction, whether by lenses or reflectors, by the help of which the sensitiveness of the receiver . . . would not need to be so delicate as when the rays to be picked up are simply radiating into space in all directions and fading away. . . .

"Any two friends living within the radius of sensitivity of their receiving instruments, having first decided on their special wave-length and attuned their respective receiving instruments to mutual receptivity, could thus communicate as long and as often as they wished by timing the impulses to produce long and short intervals on the ordinary Morse code."

This idea fired deForest's imagination. What Crookes suggested was a practical application of theories. What he described is, indeed, a picture of modern radio communication in principle and in practice. Lee was to spend a summer reading, thinking and planning his future experiments which would take place as soon as the laboratory opened.

He talked with class-mates of the time when cities would be smokeless and ashless; when power for heat and light would be piped into the city by means of underground electrical conductors from great distances, from white coke, water power from distant rivers, or from coal-burning power plants located at pit-mouths, far removed from the cities and the millions of people who were to benefit from the heat energy of the coal. DeForest himself would not go into this side of electrical engineering. That he had already determined. He went farther into his specifications of the perfect state in which the wireless transmission of intelligence would be an established fact, planned ways and means for the electrification of the railroads; described the engineer's idea of the cities that were to be. It was a great dream.

That autumn found him laboring to make at least his part of it come true.

V

In the Fall of 1896, Lee deForest was in the laboratory in the basement of Winchester Hall, trying to determine the characteristics of the electrical machines which were at his disposal. The equipment at Yale upon which those interested in practical electricity were forced to experiment was hardly inspiring. It consisted principally of two dynamos — one for alternating current and one for direct current, a dynameter, voltmeter and ammeter. Compared with what engineering schools have today at the disposal of their undergraduates it was indeed pathetic. DeForest working alone under the direct supervision of one of the laboratory assistants under Professor Hastings, found the work becoming constantly more difficult.

It was unfortunate that through all his post-graduate work as well as through undergraduate work, the mathematical courses were not designed for use of engineers. They were difficult, highly abstract, and wholly theoretical. The task of analyzing problems in physics in mathematical terms was not taken up in Sheffield until years later. The professors spoke then of "mathematics for mathematics' sake," wholly without any idea of practical application. Some even boldly confessed from

time to time that as soon as a branch of mathematics became practical it lost all its interest for them.

DeForest, eager to devote his every spare moment to duplicating the experiments of the great European investigators, found himself forced each year to take still more abstract and rigorous courses in higher mathematics. This he resented, for he was fascinated by his own ability to duplicate the experiments of the European savants in the field of Hertzian waves on long wires. Compared to this thrilling prospect theoretical mathematics looked like drudgery. It was not until several years later that he was able to appreciate the insight that mathematics gave to the forms and laws of electrical and natural phenomena. Then he was almost ecstatic in his praise of the practical power this abstract subject had given him, and wrote in his diary: "I want more and more higher mathematics for through this very special knowledge alone can I deal intelligently with light and wave phenomena in which I believe I see the big future of electrical advances."

Meantime, he had begun some experiments with electrical condensers and became enthusiastically interested in the theoretical possibilities of the condenser as distinguished from the transformer in the electrical industry.

The uses of the condenser at that time were already manifold — particularly for physics, electric designs and telephone operations, but deForest immediately saw hundreds of new uses for this device.

"The condenser is half-brother to the transformer," his notes read, "but more efficient and cheaper to develop. It may take the transformer's place for many things. With this possibility — i.e., that the condenser

may take the place of the storage battery, I see new worlds to conquer.

"My specialty then, shall be the condenser. It is the stepping-stone between the electrical art of today and the final and more mysterious 'wavy' form to which we must come. It is the ladder to the final realms of the air."

It is interesting to note that the present 1930 value of the condenser proves strangely enough the foresight of deForest's early prophecy.

During his first post-graduate year deForest also invented the "Equationer," a machine for solving quadratic roots. A detailed description of this machine appeared in the *Yale Scientific Monthly* for March, 1897, and won him considerable acclaim. But the great vision of entirely revising the electrical field proved to be temporary as he moved on in his studies, leaving the condenser far behind.

VI

So great was deForest's interest in the Hertz phenomena during his undergraduate days that he knew the complete history of every experiment which had been conducted since Maxwell's discovery. It would have been difficult to survey the epoch-making progress of the scientists without discovering that passionate experimenter, Nikola Tesla. DeForest had purchased and studied Tesla's book on Electrical Phenomena. Here was indeed a genius, reasoned the boy at Yale. Tesla became a hero, a personality to whom deForest turned with something resembling worship.

Amazing, wasn't it, how the incidents in the life of Tesla resembled incidents in his own life? DeForest knew the whole story. Tesla's father, like his own, had wanted to make a priest of the young physicist, but Tesla had found his way out of religious environment and into the front of the electrical field. An independent inventor in his own laboratory in New York, he epitomized the young Yale student's ideal! One of deForest's classmates, Ernest K. Adams, was actually a friend of this great man. Adams had even visited Tesla in his laboratory and seen some of his marvelous experiments and demonstrations. DeForest pounced upon Adams.

He was on fire to hear all about the great man: What did his laboratory look like? How many assistants had the wizard? How did he pick his laboratory assistants? Did Adams believe the great man would ever give him, deForest, an opportunity to work under him in his laboratory?

"Why don't you go ask him?" Adams suggested. "He is always willing to receive people. He'll be glad to talk to you."

It was a brilliant idea, but visiting Tesla meant going to New York, and going to New York meant railroad fare. DeForest had no money whatsoever. But he could do the next best thing: he could write Tesla a letter.

It was more of a document than a letter. Lee took infinite pains with each sentence, wrote and rewrote it many times and finally sent it off. It expressed a very intelligent appreciation of Tesla's contribution to the science of electricity, an admiration for this scientist's particular genius, and a naïve request for an opportunity to work in his laboratory. After a tantalizingly long delay an answer came, evasive and altogether unsatisfactory, but not completely refusing the young man his fond hope. DeForest showed the letter to Adams.

"You ought to go to New York and see him," Adams declared. "It would be a great experience for you."

DeForest thought it over very carefully. Yes, it would undoubtedly be a great experience to look into the laboratory of an established scientist; to see his working apparatus; perhaps even to discuss with him that topic of conversation into which students, experimenters, inventors and even journalists slipped with unconscious ease, *the future of electricity.*

"Besides," reasoned Adams, "you'll soon be leaving

here. You know the theoretical side of electricity all right — but I doubt if that's enough to get you a job in a laboratory. A contact with Tesla would be a very good thing for you."

Adams' pessimistic outlook on the subject of deForest's immediate future, determined the young man in his decision to go to New York at any cost and visit Tesla in his Houston Street laboratory.

After his conversation with Adams deForest began to save every penny he could out of the few meagre dollars sent him from home. He stinted himself on food, cut down his meals at the restaurant to the barest necessities, and from time to time, whenever he felt the pangs of hunger would not detract from his ability to concentrate, he would go without eating altogether. By saving in this manner over a period of weeks he finally managed to accumulate enough money to pay for a round trip ticket to New York.

The idea of Tesla had fastened upon deForest's mind with such force that the visit had actually begun years before he reached the Houston Street laboratory and looked into the spare, clean-cut face of Nikola Tesla. In that hour he spent with Tesla in New York he was merely reliving an experience that had happened to him many a time in the dreamy hours at Yale.

A biographer of Nikola Tesla could hardly have digested more information concerning the ideas and achievements of this experimenter than did the eager-looking young man who embarked on the night boat at New Haven on his way to New York. He knew the date of Tesla's birth, 1857, of his early delight in

arithmetic and physics, of his migration from the continent to the great scene of electrical activity, America. His diary is filled with his own interpretation of Tesla's ideas and experiments from Tesla's earliest thermo-magnetic motor and other kindred devices, about which little was published because of legal complications, to his admirable motors for multiphase alternating currents. In his mind he pictured the interview. The great man would receive him cordially, of course. Journalists had written of his pleasant personality, his winning smile. He would be eager to hear the young student's ideas, for Tesla was nothing if not open-minded, with that characteristic interest peculiar to the experimenter. Perhaps, as Adams had suggested, he might become interested in deForest's ideas, even ask him to wind up his courses at Yale and come down into the Houston Street laboratory. That would be attaining his goal even before he left the university.

At daybreak the "Richard Peck" docked at Peck Slip, New York City. The Yale student picked up his thin overcoat and made his way out into the street. It was his first sight of the great city since the Yale-Princeton football game of 1895, the city in which he would have to live and work. But instead of inspiring him it terrified him. New York had street cars run by electricity. Electric lights along Broadway. It was far advanced industrially. Small wonder that great men came here to develop their genius. But the crowded thoroughfares, the noise, the unkind jostling throngs — it was like purgatory after the peaceful City of Elms. He was frightened. What would it be like to be jobless in this town? Pictures of the future flooded to his mind as he

made his way with great difficulty to Tesla's Houston Street laboratory.

Through the hour and a half spent in eating a lunch-counter breakfast and in getting across town to Houston Street all his hopes, fears, visions that had been asleep at college rushed into being. He had only a very specialized knowledge, and the electrical field was already overcrowded. The cry was for practical, experienced men. It had already reached the ears of the men at Sheffield. He was penniless, too. When he left Yale he would be on his own literally — without money, contacts or practical experience. How long would he last, pounding the streets? Would his courage fail him now?

Houston Street! Tesla's laboratory was in a loft building. It impressed deForest as being a very high building, although there were many higher buildings in New York. He soon found the spacious laboratory stretching out over an entire floor. He gave his name to an attendant and waited, impressed and patient, for the great man to appear. After a few minutes the door opened and out stepped a tall figure, over six feet, gaunt and erect. DeForest knew at once that he was face to face with a personality of a high order. Tesla shook his hand with a powerful grip and ushered him into an office immaculate in its orderliness.

So far deForest was elated. The pictures which had haunted his mind at Yale sprang into reality. Tesla had a quick convincing manner of speaking that caught and held attention, a very high, almost falsetto voice, piercing dark eyes set in extraordinarily deep sockets, a very high forehead, and a long well-shaped nose. He was indeed all that the young man had dared to expect.

Tesla talked with him for a while and then graciously showed him all through the laboratory. The young man looked with envy at the assistants and machinists who enjoyed the incomparable privilege of first-rate laboratory equipment, and training under a first-rate scientific intelligence. At that time Tesla was still working on high frequency electrical discharges, and the illumination of Crookes Tubes. DeForest weighed carefully every word the great man said, looked at his electrical apparatus as if he were taking a photograph with his eye, and from time to time very unobtrusively volunteered some idea of his own as to the future developments of electricity in the fascinating field of high frequencies.

After the two men had gone over the laboratory they returned to Tesla's office. DeForest knew that he had little time left — he had already been with Tesla for more than an hour and he had better get in his application for a job then and there. He had wisely kept this idea out of the conversation thus far. He began by gently inquiring of Tesla whether or not he regarded the electrical field as being overcrowded.

"Judging from the number of applicants I have to see daily, it is more than overcrowded," Tesla said. DeForest was stunned. Tesla went on to explain that if he were interested in making money out of his laboratory he could take in immediately two young men, sons of wealthy merchants, and receive ten thousand dollars apiece from each father for the training his son would acquire! He hastened to explain, however, that he was not interested in the commercial aspects of electricity. He said further that of all the applicants the men with

"useless ideas," and ambitions to become great inventors were the most hopeless.

The young listener explained that he had no such ideas. He had specialized in mathematics, he explained, and wanted a position with him as mathematician. He liked mathematics. Tesla seemed interested, but the evasiveness in his letter was carried on in his personality. DeForest continued to talk. He said that he knew he had not enough laboratory experience to qualify him to come into Tesla's laboratory and assist in the work Tesla was doing, but that the time left him at Yale would mean more intensive laboratory work, and hence better equipment. He admitted that he was ambitious, but he was ready and willing to start at the bottom.

Strangely enough, Nikola Tesla did not seem to regard this attribute as either interesting or unusual. He said that he would discuss the matter further with de-Forest when that young man had finished at Yale. DeForest's heart sank. There was no promise of a job, only continued evasion. And he knew by Tesla's attitude that it was time for him to go.

Desperately, he asked Tesla about his experiments. Remembering his own sadly limited laboratory work with meagre equipment, almost invariably fraught with disappointment and error, he wanted assurance. Tesla said that "never in all his laboratory work had he ever made a mistake"! Every experiment he undertook came out exactly as he had predicted. DeForest questioned him again, but the answer was the same. He was always right, Tesla admitted.

The younger man opened his eyes. Imagine all these marvelous inventions of physics with no mistakes, no errors, no disappointments. A god indeed! Tesla fell

from his throne as with one fell swoop the scientific instinct came back into its own in the mind of Lee deForest. What Tesla had told him could not possibly be true. As he bade the great man good-bye, he was smiling, the first smile he had worn during his stay in New York. He felt for the first time that he himself had some particular power, felt it now with a deep abiding definiteness.

"I shall have to take the good old packet boat back to New Haven," he told Tesla as the great man went with him down the stairs, "because it costs only a dollar and a half while the train costs nearly five dollars. It will be a long tiresome trip — but whatever it is, it has been worth it."

Tesla's egotism had disillusioned deForest — and given him a new confidence.

THE end of Lee deForest's hopes of obtaining a job in Tesla's laboratory came at the beginning of his post-graduate work. Each Sheffield student in the engineering courses had to prepare a thesis before graduation. DeForest selected as his topic the "Delaval Steam Turbine," direct drive to a generator. It was tough, exacting work, but he was proud of the finished product and of the nice blue prints that accompanied it. It occurred to him then to send a duplicate copy to Tesla to let him see what sort of work he was doing at Yale. He waited, but no answer was forthcoming. Meantime, he wrote to the Delaval Steam Turbine Company of England, outlined his thesis and suggested that they write to Tesla to secure it. He next wrote to Tesla that if he received a request for this thesis from the Delaval

Company to send it out C.O.D., meaning that he let the company pay the express charges.

At last an answer came from Tesla. He said briefly that he did not understand what deForest had meant by suggesting that he send the thesis C.O.D. as he did not place any value upon it!

It was the bugle calls of the recruiting forces for the Spanish-American war which broke in upon the academic calm of New Haven and brought young Lee out of the concentrated life of the laboratory into a dust-filled world of marching men. Every fibre of his being responded to his country's call. Devotedly patriotic he saw in the liberation of the ragged insurrectors of Cuba America's manifest destiny in which he was determined to play his part. The inventor in khaki, however, quitting Yale in the Spring of '98 to enlist in the original Yale Battery of Light Artillery got no further on his liberating quest than the training camp.

That Spring examinations were missed by a long-limbed youth on a caisson. By the time the Battery was ready for service, the war was over. DeForest had shown that he was faithful to the deep patriotic spirit which was to motivate many of his contributions to his government in later years. But there was all that work to be made up. Back at Yale he set to work again upon his study of short Hertzian waves.

His doctor's thesis, called "The Reflection of Short Hertzian Waves from the Ends of Parallel Wires" won him, in June, 1899, his long-coveted Ph.D. Perhaps he knew about as much about the new development of the "wavy" electricity as any one else in America. He had

what is commonly called "intellectual equipment." It would not be long, he reasoned, before his expert technical knowledge would find him a job. Meantime, he had neither money nor contacts nor practical experience. Here on the Campus at Yale he meant something. But the day he left Yale, the minute he got off the train into the city of Chicago, where he fondly expected to find a welcome warmer than in indifferent New York, he would be just a man looking for a job.

The last day at Yale was not a happy one. The preceding days had yielded up their own particular brightness: the graduation festivities, the center of the stage, the presentation of the degrees. Then there were party banquets and dinners, long evenings of hilarity, pledges of eternal friendship. But all the while, whether he donned his cap and gown, whether he received the second sheepskin on the platform of Bathell Chapel, whether he danced at Savin Rock or sang the old class songs, still he was aware of the passing of time, of the future that lay just ahead, of his lack of equipment, and of his insatiable eternal ambition.

His battered suitcases were packed. At five o'clock he would take the train out of New Haven to Buffalo, and from Buffalo to Chicago by boat. Meantime, he wandered about the town with his friend, George Barbour, who was to accompany him on his journey as far as Chicago. There Barbour would go on to a job already awaiting him, and to a comfortable, well-planned existence. He, Lee, would tramp the streets of a strange city, with only an idea, seeking some employer who would believe in him.

The two young men were silent. DeForest was thinking how New Haven had changed during his six years

in it, even as Talladega changed during the years of his boyhood. Electricity in houses was no longer confined to the wealthy; even the moderately well-off people could afford it. And what a blessing it was! The town seemed brighter, fuller. Those restaurants not lit with brilliant electrical lamps were already considered shabby and out of date.

The next biggest thing in connection with electricity was "Wireless." It would soon be up and coming. Not many years perhaps until it would be in the forefront of the communication field. Then his hard concentrated study of Hertzian waves would yield him returns. He tried to think of how he would go about his first experiments once he got into a well-equipped laboratory, but to save his life all he could think of was the fact that he had had no experience to entitle him to get into a laboratory, that he had almost no money, and absolutely no connections, and that he would have to do something, anything, if he intended to stave off starvation.

The stately elms and the peace of the little town got on his nerves.

"Let's go back," he said to Barbour. Catching the note of apparent discontent in his friend's voice, he turned with him and walked back towards the campus. Back at the college grounds Lee soon left his friend and wandered off alone. Of all places, he was on his way to the basement laboratory in Sloane Physics Hall, scene of disappointment, doubt, failure, but also a setting for the greatest intellectual excitement he had ever known.

The tables in the laboratory had a thin fine line of dust, for work had ceased fully two weeks ago and the room had not yet been cleaned. The Leyden jars

which, reflecting the rays of the sun, had given some aspect of cheer and light to the room during the long winter days, were there no longer. It was an empty, dusty, dreary place.

There was something almost furtive about the young man who walked into the room. Professor Bunstead, who was partly responsible for deForest's abnormal interest in Hertzian waves, was now taking notes in his office at the extreme end of the laboratory. He glanced up curiously. One of his favorite students, but what could he possibly want in the empty laboratory?

The young man closed the door behind him, walked down the length of the room and found his old familiar table. He stopped there for a minute, as though he intended to sit down — then quickly passed on to the cupboard. A great clatter and commotion followed as he took down jars, batteries, wires. In a few minutes he had made a "mess" in the empty laboratory. His curiosity aroused at last, the professor walked out suddenly and called across the room.

"What are you doing, deForest?"

The young man's face went pale.

"I — I am working," he said.

"This is a funny way to be working. Isn't it about time you and Barbour took the train? Besides, you've graduated now. Your work here is done."

Lee deForest looked guilty.

"I was just thinking about going on to the city. Don't know how long it will be before I get into a laboratory again — and I thought I'd like to be here once more."

The professor laughed mildly.

"But I thought you were bent upon bigger and bet-

ter laboratories. I thought you were going to be a great inventor."

DeForest did not answer. Of course, it was a foolish gesture. He felt embarrassed.

"Better put those things away," the older man concluded. "You have finished with them."

There was something impressive in his words. The younger man caught the intonation.

"Don't be afraid of the city. Don't come back to your old haunts for confidence. You do not need it. You have something else. Go on to bigger laboratories, to a greater confidence. Don't stop here. Go on. . . ."

DeForest lifted his head. He shook the hand of his professor, cleaned up his mess, closed the doors of the cupboard and walked rapidly down the corridor.

The prospect of Chicago lay before him. Now he was unafraid.

PART THREE

THE FIRST INVENTION

I

IN Chicago, deForest's first discovery was the Crehar Library. By contrast to his room, which always echoed with street noises and the hum of voices in nearby rooms, this institution was a sanctuary. The habit of study had fixed itself firmly upon him in the past six years, and so, reading over some technical work dealing with his pet subject, Herr Hertz's waves, he would find a temporary relief from his abiding melancholy.

This library carried a complete file of technical works, a happy find for deForest who liked nothing better than to go through all the foreign journals religiously. These journals became a source of paramount interest to him, the one relief from the dull grind of his job in the dynamo factory of the Western Electric Company's Plant at Clinton Street, Chicago.

One night he came upon an item of unusual interest to him. Notes on various experiments made by a German professor in which a new detector of Hertzian waves was described. Lee read eagerly, impressed by the stark simplicity of the device.

It consisted of a piece of tinfoil pasted on a glass plate. There was a razor slit through the center of the

metal. Across the slit, a drop of water was poured, and the tinfoil ends were taken as terminals. In operation it was exactly opposed to the Branly Coherer, a device then in use for detecting wireless signals. It broke the circuit upon the passage of Hertzian waves.

DeForest was fascinated. He took voluminous notes on the device, for he had already decided to use this very idea as a basis for his own experiments. He had long ago decided that some other method would have to be substituted for the Branly Coherer which was bulky and required "tapping" to break its conductivity after the passage of each signal. It was a simple beginning and it would cost him little money. It was indeed ironical that the cheapness of materials was all-important to the one man who had so much to contribute to the then new field of wireless.

DeForest had long considered the old bulky coherer system as being extremely inefficient. Meantime, in every spare moment devoted to reading the findings of the Europeans, he had been looking for just such an idea. At this time Marconi was signalling several miles with the coherer. What the Germans described was merely an experiment that proved the existence of the responses. DeForest immediately went further.

"Here," said deForest, "is my idea: I can make of this device a practical receiver for wireless telegraphy."

He immediately purchased the materials and set up his experiment on a small table in his bedroom. Now he had something to go home to at night, if it was only a piece of tinfoil, slit in the center and stretched upon a plate of glass.

And in the Western Electric Plant, too, things began to happen. Sometime towards the middle of October,

1899, the foreman of the Dynamo Department came to tell him of a dubious "advance." He was to be given a place wiring switchboards in the telephone department. It was not interesting or stimulating work, but at least it was clean — and he was left alone. He wrote in his diary:

"Oh, the luxury of getting to work at 8:30, of actually learning something and of associating with equals. Here, if ever, I can invent and have my ideas count for something. I study blue prints and apparatus during spare moments, and at night come back to my bedroom to go deeper and deeper into the fascinating world of wireless. I feel that I am on the first rung of the ladder. It is very high and it grows wider and wider as I mount, *but I can climb.*"

ACTUALLY for the first time in the young man's life, a sort of comfort was creeping in. His work interested him. By evening his mind felt free and stimulated, and he would return with eagerness to work on his experiments. His two superiors, John McBerty and Robert Dean, seemed to feel friendly towards him. Indeed the whole aspect of the universe had changed overnight.

Unfortunately, he knew he had been placed in the laboratory to take the place of another worker, who was then on vacation. Whenever reminded of this, a sickening sense of trepidation would steal back on him. Of course, he reasoned, they would throw him back into some other department when the regular man returned.

The weeks ended. Dean came to him one day and told him an exciting piece of news. He liked the young man's

work and the interest he took in the experiments. He could stay on the job in the telephone laboratory permanently if he wanted. DeForest was breathless with gratitude.

"Do you think I might use the laboratory some time?"

"What for?"

"Why, for my wireless experiments."

The boss smiled sympathetically. Wireless was an untried experimental field, he said, but a vastly interesting one. Encouraged by this sign of intelligent understanding, the young man spoke out. It was his first opportunity in Chicago to talk to an intelligent listener. He described his work on the anti-coherer, outlining the idea and carefully describing his findings. McBerty came over, and the two listened eagerly. They made no comment, but the following day Dean asked deForest if he could reproduce his experiment in the telephone laboratory. He had eagerly awaited just such a suggestion. He set to work at once, rigged up an old spark coil and condenser and duplicated the apparatus first created in his hall bedroom. The men drew close and just as deForest had predicted they heard the little crackling sound in the receiver. It worked.

McBerty and Dean were frank enough to confess their interest. They admired the simplicity of DeForest's apparatus. They pitied him for his amazing efforts in the barren bedroom. Dean said that he could use the telephone laboratory for his own experiments, provided, of course, he would not take time off from his telephone work. This was just the opportunity for which he had longed, for thus far he had not dared

work on any of his own ideas for fear of being discovered and fired.

From that minute on his efforts seemed to have meaning. His habit of walking about Chicago trying to find an edible fifteen-cent steak was suddenly discontinued. Lunch was a speedy affair. He would snatch and devour a sandwich and rush back to the laboratory, to spend the rest of his lunch hour on his wireless apparatus, beside which food seemed a petty and tiresome detail,

II

His work grew in interest as he went along because already he had made an amazing discovery: that of using the telephone receiver as the indicating device for wireless signals. Here was indeed the original of the radio telephone receiver. Simplicity of operation and high speed telegraphy were to be the inevitable results of this remarkable idea.

DeForest realized that he had been hired for telephone work, and that his own creative and inventive work was something to be sneaked in during his lunch hours, in the evening, and in the early morning hours, before the day began, but it became increasingly difficult for him to keep away from his own work.

As time went on, however, even against his better judgment, he went more and more into the wireless phase of his work and devoted less and less time to the routine experiments of the telephone laboratory.

Meantime he had been given his first raise of two dollars a week, making his salary now ten dollars.

One day Dean, who by this time had gained rather a shrewd sense of the value of deForest's ideas, and who secretly figured deForest would do just as valuable work for the company in his chosen line as he would

in the improvement of the telephone, stopped short and eyed him closely.

"Look here, deForest," said Dean, "you'll never be a telephone engineer. As far as I'm concerned, you can go to hell in your own way. Do as you damn please." With those words he turned on his heel and walked away. DeForest, with typical recklessness, took him at his word. He turned back to his wireless experiment and continued at it all afternoon. And next morning he started upon it early in the day and continued at it completely oblivious to the telephone work going on about him, and for which he was being paid. This complete concentration upon his own experimental work soon brought him amazing results.

Following the original German idea, which had possibilities but was out of the question as far as practical working was concerned, he noted that his apparatus would function properly for perhaps only twenty or thirty seconds at a time. This trouble he easily traced to the fact that the water lying in the gap in the tinfoil would pass into a state of semi-decomposition with the passage of the small currents. Immediately he began searching about for other electrodes and cohering substances. He tried everything. The difficulty itself fascinated him. In spite of Marconi's amazing achievements, wireless was still in its laboratory state, the second step in the metamorphosis of an invention. The mere fact that no one particularly wanted to communicate without wires made it all the more interesting.

Although deForest's concentration upon his experiments was too confining to permit of much contact with the outside world, his ideas had begun to arouse interest. For instance, he had made the acquaintance of

W. W. Smythe, an engineer with the Western Electric Company, who was more than casually interested in what deForest was doing. Besides, this man had just the qualities deForest needed to stimulate him and keep him going. Smythe was a practical, modern, electrically-minded engineer. He was quick to grasp the significance of deForest's experiments. Smythe watched deForest's work with interest, discussed the various problems with him, and, from time to time, gave him helpful practical criticism and advice.

This was just what deForest needed. He began to feel that his receiver, or responder, which he affectionately termed his "sponder," had some merit and might some time be patented and financed.

One day, while in the midst of an experiment, an office boy came into the laboratory and handed deForest a card which read "Professor Johnson" and bore a Milwaukee address.

DeForest had no idea who the man was. He questioned the boy closely, but no further information was forthcoming. As he put away his materials preparatory to joining the man in the waiting room of the plant, he began to wonder: could it possibly be the one and only Johnson of whom he knew, an inventor of some note, who had designed a system of vacuum control for steam boilers and radiators? No, it could not possibly be the same man, for what on earth could such a man want with him?

Downstairs in the waiting room he found himself greeted with considerable warmth by a tall, middle-aged individual who gave off an air of well-being not char-

acteristic of inventors in general. "No," deForest concluded at once, "it could not possibly be the same Johnson."

The man seemed eager to get to the point.

"I have read considerably of wireless experiments, and I recently learned of your work in the field of the coherer," he said. "I believe that I have a possible improvement upon the present coherer."

Eager to hear and see what the man had in mind — for any improvement in the coherer meant better reception, a step nearer the goal — deForest invited Johnson into his laboratory.

They began talking eagerly together, each plying the other with his ideas. Although deForest had at first hesitated to ask the man pointblank whether or not he was the Johnson of whom he knew, he found, through the man's own conversation, that he was the self-same inventor whom deForest had thought far beyond such a visit to a much younger and inexperienced inventor. DeForest said modestly that he was grateful for Professor Johnson's interest in his work. Johnson replied that he had a motive in his visit: He had learned of deForest's experiments and had come to Chicago to seek his services in developing his own system of wireless telegraphy.

"How would you like to come into my laboratory?"

"In what capacity?" deForest naïvely inquired.

"That of chief engineer."

DeForest was too astonished to do anything but stare at the man.

"I don't know what you would expect in the way of salary," said the professor, "but I feel sure we could

come to terms. Have you anything in mind — any figure, I mean?"

But the mind of the young man, who was after all just an isolated youth experimenting in the laboratory of a great city, was crowded with bright pictures. So this great man had heard of him and actually come all the way from Milwaukee to pay him a visit — and what a visit! — to offer him a job as chief engineer. That meant a laboratory would be his, the tools would belong to him, his time would be free to work upon the thing that was dearest to his heart. From what seemed like a vast distance, the voice of the professor came back to him.

"Well, Mr. deForest, what's the answer? Will you come?"

DeForest said he would.

"And what salary do you want?"

Down to earth, deForest wondered how much he dared ask for. Eleven, twelve, thirteen dollars — would that be too much? Suppose he made it fifteen?

"How is fifteen dollars a week?"

The man smiled.

"Do you think you could live on that?" he inquired.

"Indeed, yes," said deForest. "When do you want me?"

They made their arrangements which included a check for a week's salary in advance and full railroad fare.

Two weeks later all of his drawings, blue prints, precious apparati and diaries were packed into the suitcase that was fast becoming an heirloom, as he took the train for Milwaukee. It meant nothing for him to leave Chicago. He was convinced there were great things ahead.

III

It was in May, 1900, that deForest arrived in Milwaukee, and was met at the station by Dr. Johnson who was all too eager to be in the invigorating company of the younger man, to listen to his ideas and to talk of his own.

"I'm planning to install a transmitting station in the laboratory this week," Johnson said, the minute the two men met.

DeForest immediately inquired what arrangements had been made for the receiving ends, especially what his own particular job would be. Johnson's next words convinced him that something might be accomplished in Milwaukee, though in what manner he did not dream.

"I've looked at a little shack beyond the city limits — in fact, I plan to go out and rent it tomorrow. There we'll install the Johnson-Fournier automatic receiving set. You will be stationed out there — and make every possible effort to pick up the signals. Then we can compare notes — and work out any ideas we have together, in the laboratory."

Meantime, in mulling over Johnson's idea of a wireless detector, he had decided that Johnson was wrong. What the professor was doing was deliberately turning

from the very principle that Marconi and other experimenters had found to be sound. It was generally known that an advantage was gained by placing the filings in a vacuum, because in this manner corrosion, caused by the ever present moisture in the atmosphere, was prevented. The professor deliberately inverted this idea and blew air into the filings!

But however unsound was Johnson's idea, deForest had at least the consolation of being away from a laboratory whose work had for him lost its lure. Here all was new and untried. Anything might happen. He had a plan, right here in Milwaukee, of how to make something happen.

And something did. In the first few months deForest spent in Milwaukee, there was freedom from poverty amid pleasant surroundings in which to contemplate his existence as a whole without the strain of trying to work out an idea against time, as indeed had been the case in the telephone laboratory of the plant in Chicago.

Johnson had built a small shack in which deForest had installed Johnson's own idea of a receiving set. This was situated on the edge of Lake Michigan. In his very first week in the shack, waiting not too patiently hour by hour for the signals to come through, deForest had arrived at the conclusion that his estimate of Johnson's idea was scientifically sound. To continue to work with it would be for deForest a waste of time.

It so happened that at this time deForest had been given an assistant, named John Lyman, a cautious little fellow, whom Johnson had sent to work with deForest

and lend him every possible aid. This Lyman was an earnest soul, a good machine man, but he had no idea what deForest and Johnson were doing, or indeed no idea altogether aside from the interest of his concern. But deForest, while working futilely hour by hour with the Johnson-Fournier automatic receiving set, which he had secretly entitled "the Johnson-Fournier *non*-receiving set," he had gotten into his brain again the self-same plan that had occurred to him during his first conversation with Johnson. He was wasting time with this set of Johnson's. Dared he take out and experiment with his own set? Would the dull little machine man know what he was doing? He decided he had better wait until Lyman was out.

One day, while Lyman was having his luncheon, deForest dug out his own little set from the precious box he had carried with him from Chicago and set up his "sponder." Within an hour he was steadily receiving signals from Johnson's laboratory. Excitement! He lost all thought of time and place. In his concentration he did not even hear the footsteps of the little man walking down the road. Lyman came in — and found him. DeForest glanced up in the midst of his joyous work. The two men looked at each other and said nothing. DeForest felt instinctively now that it was only a question of time before he was discovered.

Later that evening he put the sponder away, locked it up in his box. Days passed and nothing was said, and the machine man was the same earnest, well-meaning little soul he had always been. DeForest felt more comfortable. He began to think that possibly Lyman had forgotten the incident, and that he would not be compelled to deliver up his precious idea — or else go back

to a hall bedroom and the horrible prospect of joblessness.

At the end of three months, the professor had still made no progress with his work. He had spent several thousand dollars and still no single improvement had been made over the original Marconi works. The experiment could not last indefinitely. DeForest knew that it was only a question of time. It was Lyman himself who brought the experiment to a climax. He saw that his job was going to end. Desperately, he made his plea to deForest.

"Why don't you give your Sponder to the professor and start work on that line for the company?" Lyman had found out after all what deForest had been doing.

DeForest would not listen. He had conceived the idea long before his entrance into the service of the professor, and so considered it his own property.

Next morning Lyman told Professor Johnson of the Sponder and of its success in preliminary tests. He had seen the apparatus, had helped deForest in some of his work, which had given him an acquaintance with the Sponder, and a working knowledge of its technique. He described it as best he could to the professor. This seemed most logical to Johnson. They were getting nowhere. They were wasting money.

The following day deForest was called to Johnson's office. He felt instinctively that Lyman had "squealed." That was the price one often paid for one's recklessness. DeForest came at once and faced Johnson.

It was a short interview, although its results have proved far-reaching. The professor asked deForest if he

had any suggestions to make as to possible improvements in the apparatus. DeForest replied with a few commonplace details about the mechanical design of the apparatus they were using. The professor said he thought some other line of investigation might pay better in the end. DeForest did not evade Johnson's keen glance as he steadfastly maintained that he had no other ideas to offer upon the subject, no other line of investigation upon which to start.

The professor changed color. He was frankly furious, and now he made no effort to hide his indignation. He told deForest what the young mechanic had said.

"Are you going to be a fool and refuse to permit us the benefit of your knowledge?"

"It is not a matter of knowledge," the younger man replied. "It is my invention. I do not yet know what practical possibilities it possesses, but I believe in it and I will not let it go into the hands of any company until that company is mine."

The two presented an interesting picture, if only as a study in contrasts. Johnson, comfortable and middle-aged, a man who had money and success, making a plea for an idea that his own brain could never have conceived. DeForest, lean and young, facing poverty again, a hall bedroom by night, by day the streets of a big city, with nothing in all the world save faith in an idea.

"In other words," cried Johnson, in a blaze of fury, "you refuse to turn over your ideas to my company?"

"Exactly," replied deForest.

"Then you had better get out," replied Johnson. "The quicker the better . . ."

DeForest bowed and left the presence of his employer,

who with all his worldly goods would be forced to face the failure of an idea.

Whereas a kind of feverish excitement tingled in the veins of the young inventor. Milwaukee had at least shown him the value of his beloved Sponder. He would go back to Chicago and stand by the Sponder — to sink or swim. As to the penury that faced him, he was used to working in the face of poverty. The prospect of going back to the city was even alluring.

IV

To an outsider looking upon the seemingly forlorn young man returning to Chicago from a sojourn which had promised such brilliance and had yielded such distress, it would seem that deForest had little to live for. After all, the young inventor who alighted from the train at Chicago in September, 1900, with only the "Sponder" in its box, was in much the same position as the young Yale graduate who came to Chicago in 1899 with only an idea in his head.

Without thought, he went directly to the same rooming house he had hated during his early days in the unfriendly city. He went upstairs to his narrow little room, which had been but recently vacated, and looked upon the same close-up of the laundry, the same frail morsel of sky.

"I'll take it again," he told the woman, "this time not for long, I hope."

The night passed somehow. Morning found deForest calling upon one of his friends in the electrical industry. The only job the man knew of was on the "Western Electrician," a publication of some note, and was apparently still open. The man did not know what it was

about, but the editor was a nice chap. He seemed to think deForest would get the job.

DeForest lost little time in getting to the office of the "Western Electrician." The editor was a polite and kindly individual, but his word concerning the job was neither polite nor kindly. First, it was a purely temporary job; second, it involved translating from the French accounts of the World's Exposition that was being held that summer in Paris; and third, the salary was ten dollars a week. DeForest said he would gladly take the job. Because he knew scientific French, the translation of scientific descriptions was extremely easy work, and he would at least be saved from facing the problem of job hunting. The editor said he could have the job.

So life began again in Chicago, with a small job, a smaller hall bedroom, but an idea that reached across millions of miles, defying time and space.

THE very next Sunday deForest found an advertisement in a newspaper — he was forever reading the "Help Wanted" columns — for a teacher in an electrical laboratory at the Armour Institute. An idea flashed into his mind: Why not swap a few hours of teaching time for the use of one of the laboratories? It would mean more to him than money for by now he had gained his own notion of the value of money. If one had so little to live on, what did it matter whether that little stretched or diminished? He could teach after hours at his job at the "Western Electrician." Besides, that job would soon be over.

Accordingly, next morning he went to see the

Director of Armour Institute. The visit brought him what he considered a highly satisfactory arrangement. For teaching just three hours a week, he was to have free run of the electrical laboratory in which to continue his experiments. He would not be paid for his hours of teaching, of course, but the laboratory would be entirely his own. He set up his Sponder and went to work. It became better and better in its result.

But deForest felt irked under the necessity of splitting up his time between experiments on the Sponder, a source of great excitement to him, and teaching dull young boys. Would he never be able to work uninterruptedly on his own invention? Would he always have to stop and turn his attention and his time upon some petty and absurd details, hour by hour, day by day, for the sole purpose of paying for his meals and his bed? Wasn't there a single human being in Chicago sufficiently modern-minded to see the scope and magnitude of his idea and who would be willing to give him the few necessary dollars to launch the invention?

He was not long in calling upon W. W. Smythe, the engineer at the Clinton Street Plant of the Western Electric Co., who had already shown deForest both interest and confidence in the Sponder. Besides, deForest's Milwaukee venture had shown him that what he now needed was a practical modern-minded electrician, preferably someone with money, or failing that, someone who was at least well established in the electrical business and who had (the young inventor was fast beginning to realize the importance of the word) "connections."

Smythe was very glad to see deForest, who frankly admitted that his Milwaukee venture had been a flop, but

it was certainly not a failure as far as the Sponder was concerned. Smythe had only to look at his notebooks to see the various tests deForest had made during his Milwaukee stay. Smythe was greatly excited. What a relief was this young man, already afloat upon the untried sea of wireless, beside the dull routine of Smythe's daily job as a telephone engineer. DeForest said that he needed someone to work with him. Smythe was not long in making his first practical suggestion that they take out a patent for the "Sponder." That would serve well as a practical symbol of their new partnership.

It was ironical that, after the hardships deForest had undergone for the sake of his idea, not even his first patent could be completely his own. First because he had no money and the patent had to be financed by Smythe who was making what was considered the goodly sum of a hundred and twenty-five dollars a month; and second, because Smythe had contributed some practical ideas. The more intimate name "Sponder" was abandoned in favor of the more accurate patent name, "the electrolytic anticoherer." It was simply an automatic detector that made possible the use of the telephone as a receiver for wireless signals.

The taking out of the first patent, probably because it was the first practical step in the slow progress of his idea, served as a kind of an impetus. DeForest and Smythe began working day and night on the Sponder in the laboratory of the Armour Institute, beginning just where they had left off during deForest's experiments in the telephone laboratory of the Western Electric Company. They first tried various different electrolytes in place of water which had proven so undependable: gylcerine, benzine, olive oil, even gaso-

line. Sometimes it would seem as if they could never find the right medium. Then argument followed, note-taking, and at last a new idea would emerge.

Voluminous notes. The first experiments proved that tin worked well in combination with silver. The entry for Saturday of that particular week reads that "experiments were temporarily suspended, since the experimenters had to eat over the Sabbath."

Meantime, in order to give more time to his laboratory work, deForest talked to the editor of the "Western Electrician" and asked him to cut his services into a half-time job. A part-time salary followed, barely enough for sustenance.

One Sunday night, deForest walked into a concert hall and paid a quarter for standing room. As he paid the quarter, a thought flashed through his mind: he might have used that coin as an electrode in tomorrow morning's experiment.

It was warm and dark in the concert hall, and vibrating with the strains of Beethoven's "Fifth Symphony." He stood enraptured. The "Fifth Symphony" had been his favorite in college and at home. As far back as he could remember, there had always been a deep response to the strain of fine music. He was glad he had come. The music made him over for it captured for him the fine high courage of his youth, which was temporarily lost. He drenched himself for an hour in the melodies of the old masters, and came out believing in himself and in life, and possessing again that inner resource which made the labor of his days seem bearable.

Each Sunday after this found him climbing countless steps to reach the highest gallery where he had purchased the cheapest seat in the hall to listen to Beethoven

or to Wagner. His contact with the incomparable music of the old masters, under the strain of his present life, suffering sometimes from hunger and always in a state of feverish excitement, left a deep mark upon his character and helped to develop a response to beauty that sets out deForest as a rare individual among inventors.

SMYTHE believed in the "Sponder"; so did deForest; nevertheless the awful nagging chorus kept sounding in his ears, "getting nowhere." His part-time salary on the "Western Electrician" was barely enough for sustenance. He wrote:

"Oh, the loneliness, the difficulties of these days. I have no place to work. No facilities. And I have to earn my food. Smythe's aid is and has been small enough for a task of this magnitude, an invention of this scope and difficulty. I am dwelling in a new realm. All in the dark. No precedents. No theory to guide. No apparatus. No co-workers. All things to be tried out and tested.

"Thus, under such encouraging auspices and with such magnificent support, I begin to lay the slow and tedious foundations of a lengthy and most difficult research. Even in my laboratory I am often intruded upon. At least one full day a week I must turn from my work and pay for the use of the laboratory. Never can the experiments go in full swing for lack of instruments properly built. Time is short. Marconi is headed towards America with his wireless detector, and I alone can pilot this weather-beaten craft. If it cannot meet him next Spring, it may as well sink now. And if it sink, I sink deeply with it."

And then, turning from the tense ambition that besieged his days like a sickness, Lee deForest would listen to music. Great music: at that time in Chicago it was possible to hear grand opera presented by a really fine opera company, the Henry Savage group, called the Castle Square Opera Company, for exactly twenty-five cents. Always enthusiastic, always ready to share his happy experiences in order to give happiness to whomever was close to him, whether for a moment, an hour or a year, he was not long in communicating the spiritual uplift of the opera he had discovered in Chicago.

"You must come along," he suggested to Smythe and his brother. "We will return to our work revivified. And it's only a quarter."

After that the days in Chicago were not without their bright note. Saturday night at the Studebaker theatre found deForest in the center seat of the first row of the balcony with Smythe at his side, listening to "Aïda."

V

It is ironical enough that in a room which deForest describes as "the smallest boundary of space in the world," the inventor first conceived the idea for the Audion, an invention which has helped to annihilate distance.

The invention of the Audion tube is a modern phantasy. Exciting, pathetic, awe-inspiring, it is still one of the most amazing conceptions of any scientist who has been present at the uncanny assassination of space.

One night in his tiny room, impatiently awaiting the time when he would give his wireless receiver its first long distance test, deForest was seated near his little "Sponder," operating the transmitting key by means of a spring. Suddenly as the coil sparked the gas light became dimmed. He cut off his coil and the light rushed back into the gas mantle.

Here, then, was something new. Why indeed should the gas mantle respond to the spark coil? What was the relation between the two? He tried sparking the coil again and again and each time the light in the room dimmed, and then brightened as the coil sparked and died. This was a phenomenon of a rare nature. In and about the incandescent mantle was matter of a very re-

sponsive and unusual character. If it responded in this manner to the sparking of the coil, might it not indeed respond in some such manner to Hertzian wave vibrations? In which case the most delicate variations of these marvelous waves, never inert or indifferent, always generating currents of an unfathomable frailty, would have a new receiver. It was indeed a discovery. A new method of detecting, more sensitive than anything yet discovered. With the curious instinctive shrewdness of the scientist, deForest foresaw that here was something entirely stable which needed no attention and changing of polarity during operation, as, for instance, did his "Sponder."

He rushed into Smythe's rooms. Smythe was greatly excited. The two came back to the deForest bedroom and began a systematic investigation of the new discovery. First they analyzed the mantle; noticed its shape and heat and wrote down a complete set of notes on every possible contigency. There followed a discussion, full of high hopes and practical ideas. It was difficult for deForest to fall asleep that night. But days passed before he could get back to the laboratory and actually test it out. Meantime, he was anxious, uneasy. He counted the minutes until he could give his idea its acid test.

Alas for most of the glamorous illusions of science, he would not have been in such haste had he foreseen the bitter disillusionment that was to follow. At last he set up his experiment in his laboratory, lighted a Welsbach mantle, and waited. As soon as the spark coil was removed to another room and the door closed so that the sound of the spark could not reach the mantle, the light fluctuations disappeared. After repeated experiments, it at last became obvious that the sound waves

from the spark gap caused a change in the gas and air currents within the mantle, forcing the gas from the hotter regions down to the less dense spots which were not quite so brilliantly lighted, thus causing the distribution of the gases to be more even throughout the burner. This happened again and again.

So it was an acoustical phenomenon. Smythe was satisfied that deForest had discovered nothing at all. They sat down in the laboratory together, and the young inventor listened to the practical intelligence that was slowly tearing his theory apart. He nodded his head in agreement.

"All right," he said at last. "I guess we'll drop the whole idea."

What he was really thinking, however, was something entirely different. "If only I had the time to investigate, I know I would discover an entirely novel method of Hertzian wave detection, something that might indeed challenge the progress of science in this direction, that might make possible the transmission of code and voice and music across thousands of miles. . . . If only I had time! But the race is on for a wireless detector. The fight is getting too close to leave now and go off on any new line of investigation. But I will think about it in all my spare time. I will take notes upon whatever ideas occur to me. I will await the time when I can turn again to this fascinating field for investigation, and I know that there awaits a discovery, although I cannot prove it. Perhaps in a laboratory of my own, I can create something that I *see* even now and of which others do not even dream!"

In other words, so highly developed was the intuition of this scientist, he even then sensed the true power of

his idea. He had no time to work upon it. There were practical matters on the difficult financing of the anti-coherer. Nevertheless he thrilled to the thought that the incident of the gas mantle had not ended. He even sensed that it was doomed to be held in abeyance for a few years, although his imagination could not quite see that it would emerge later in the form of the three-electrode vacuum tube which has made possible the present-day development in the science of radio.

It was in the summer of 1901 that deForest and Smythe agreed to give the "Sponder" its first long distance test. Smythe was to press the key of the transmitter which was in one of the upper halls in Armour Institute. For transmitting antennæ, the pathetic original of what is now called the bird-cage antennae, deForest had taken a barrel and removed the hoops. These barrel hoops he joined with ordinary wire which he brought together. It was with great delight that deForest and Smythe arranged the hoops fifteen feet apart on the roof of the Lakota Hotel, starting at the top of a flag pole. Carefully they unbraided yard after yard of lamp cord, the one means they saw for obtaining sufficiently flexible wires. All of these wires were joined into one single wire at the base of the antennæ which led in through the window off from the roof and ended in the spark gap. The other end of the spark gap went through a steam pipe to the ground.

It was an exciting day. The dreamed-of was about to come true. It had been raining and the slate of the roof was slippery under foot. When at last the antennæ were erected, he set his precious Sponder box on the

parapet. He connected one antenna wire to one binding post; the other to the iron pipe on the roof.

The manager of the hotel, who had given deForest permission to erect the antennæ, suddenly opened the window to inform this crazy inventor that a storm was about to break, and to suggest that he put off his experiment until some time later in the week. DeForest smiled at this. He had brought along an old umbrella which he now opened as the first drops of rain poured down upon his precious apparatus.

The Armour Institute was half a mile away. Smythe was to press the key at 3 P.M. It was now ten minutes to three. DeForest had set his watch. While the rain poured down in sheets upon the roof, he stood quite still, breathless with excitement, his battered umbrella insufficient to stave off the windswept rain, a lone figure in an obscure but nevertheless gigantic drama of physics. Five minutes to three . . . four minutes . . . and then three o'clock. A faint whrr-whrr came upon his waiting ears, ticking the h's of the agreed signal. He listened. The signals ticked on, growing louder and more distinct. No music he had ever heard sounded half so sweet as these seemingly insignificant little sounds that fell upon his ears; no mystery half so profound as their transmission through the streets and people and buildings of Chicago. He looked up across the breadth of sky above the hotel. "Space," he was thinking. "Silent; timeless; frightening. Now it has a presence; now it is a world of potential life and meaning."

It was possible for man to chart at last part of the breath-taking infinity of space. He had actually *listened* to sounds sent through space without wires. There only remained for the scientists to create machines for using

more and more of this sea of electric life. The impossible was happening there. He looked off into the storm clouds gathering darker and darker over the roof of the Lakota Hotel. He seemed to see for the first time an invisible architecture stretching the length and breadth of the universe, growing higher and wider with time.

VI

In the excitement following his successful reception on the roof of the Lakota Hotel, deForest believed more than ever in the great future that awaited his Sponder. It was only a question of completing more trial tests at greater and greater distances. One week later, still inspired by the success of the experiment, deForest planned a five-mile test between a steam yacht and the "Four-Mile Crib," a stretch of Lake Michigan waters. The results were amazingly encouraging. DeForest decided once and for all that nothing could stop him from taking the apparatus to New York and reporting the international yacht races of that year for one of the papers. The newspaper stories alone would stimulate the public's interest in wireless. After that, so vast was his confidence, he believed it would be an easy matter to interest capital in his device.

He set out to interest Smythe and a young Chicago inventor named Harry Freeman, who had invented a sending apparatus, insisting in his usual impatient manner that this was the only course to follow. He showed them a clipping from one of the Chicago daily papers of a story concerning the forthcoming yacht races between Sir Thomas Lipton's Shamrock II for Great Britain.

and the Columbia as entered for the United States, to be held off Sandy Hook in New York Bay. It would require financing, deForest said. Smythe and Freeman hesitated. DeForest was adamant.

"There's hard work ahead of us. Let's not waste time discussing whether or not it ought to be done. It's *got* to be done. This is the one logical course to follow; the one sensible way to bring our apparatus before the public; the one hope of interesting capital in our device."

Said deForest:

"We've got to make the necessary arrangements, and the sooner we do it the better for our plans. Besides, if we use that sending apparatus of yours, Freeman, we want to have some time ahead to experiment."

"My sending apparatus is the most logical one outlined to date. I don't know of any better," said Freeman.

"I don't see the reason for rushing," added Smythe. "Besides, it's only a stunt. How do you know it will lead to anything? None of your stunts have."

DeForest stared at them in amazement. A dreary sense of the drearier truth crept in. After all these years of planning and experimenting, of trying, first one idea and then another, and at last achieving their goal, these two men still could not see the undertaking for what it was. He still had to sell them the idea.

He began to tell them of the work of Marconi. By this time, Marconi had done great things in Europe. The Wireless Telegraph and Signal Company had been organized in England to buy Marconi's rights. The Italian Navy had adopted wireless telegraphy. By 1898, Marconi had established wireless communication across

the English Channel. The principal steamship companies were already beginning to equip their vessels with Marconi wireless sets. Greater and greater distances were being connected. Couldn't Smythe and Freeman possibly see what it would mean to get into the running immediately? DeForest told them again and *again* that the only reliable method for receiving wireless messages was through the use of telephone receivers. It was only a question of time before the public was made aware of the importance of this idea, before ships were all equipped with wireless telephone receivers, before there were scores of coastal stations handling traffic, before they were all millionaires?

They said nothing. DeForest looked at them. Suddenly his patience gave out.

"Answer 'Yes' or 'No,' " he said. "If you don't want to help me with this idea, I will get someone else."

Thus far in the various instances in the course of his relations with his co-partners where deForest had been forced to assert himself, both the two men had yielded. Even now they began slowly to weaken before the strength and courage they recognized in deForest's clear-cut words, and saw in his keen eyes. It was Smythe who spoke first.

"We can't lose much by trying to make the arrangements."

"And with my sending apparatus," added Freeman, "we may even succeed."

It was easy for deForest to be magnanimous.

"We will use your sending apparatus, Freeman," he said.

One week later, deForest, his apparatus packed carefully away, boarded a day coach for New York. As soon

as he arrived he made his way to the Associated Press offices.

His method of arranging to cover the yacht races was characteristic. He had always gone directly towards what he wanted. He was too much interested in the idea ever to be bothered with employing salesmanship methods in putting that idea before people. For instance, in this visit to New York, so positive was his belief in his wireless apparatus, so eager was he to get on with the necessary and interesting arrangements, it did not occur to him that the event of the races would be a turning point in the history of wireless telegraphy, that the whole incident might well have made or ruined his own contribution, and hence required the greatest tact and concentration. His method is certainly in his favor as a human being; he asked for no introductions, not even a letter, inquired from no one even so much as the name of the executive of the Associated Press, who was in a manner to decide his fate. Whoever that person was, reasoned deForest, if he had the intelligence, he would see the value of the idea and give him his chance.

But at the offices of the Associated Press he found that neither courage nor faith had anything to do with the situation. The Marconi Company had had the same idea, and had already contracted with the Associated Press for reporting the races by wireless. The editor who gave him this information spoke in a calm, and to deForest, nerve-racking voice.

"We signed the contract many months ago," the man said. "We believe it will be a great success."

DeForest nodded, thanked the man for his courtesy and got up. In the outside office he stopped to collect

himself. His quick mind came to his rescue. The Associated Press was not the only news service. Why not try another? He remembered having read stories reported by the Publishers' Press Association.

He went to the offices of that organization. The manager saw him and more than that he saw the importance of the idea. The interview was not much longer than the last, but it was far more exciting. The man snapped up the offer, put deForest under contract and agreed to furnish the tug for following the boats. DeForest went away elated.

The details of his existence from that minute on would not indeed seem even remotely productive of happiness. He had only a small amount of money left over after his train fare, the few dollars loaned him by Smythe. He could manage to pay for a small room somewhere, another hall bedroom, but he could not even contemplate paying for the materials with which to construct his apparatus, much less the use of a machine shop in which to work. Now then a new situation presented itself. This project would have to be financed. He dared not ask Smythe for more money; he dared not ask the press association that had hired him; and he dared not lose a minute.

There was only one person he knew who had an office in New York, a business man named Seidler whom he had met in Chicago through an old college acquaintance, Manning Stires of Jersey City. As soon as he had found himself a place to sleep, he looked up Seidler and made an appointment. The man was cordial, seemed anxious to see deForest, and to his utter amazement confessed at once that he had just arrived from Chicago with a little spare money which he wanted to invest. DeForest

spent four hours in Seidler's office explaining in detail first the scope of the wireless, where it came from, whither it was going, how it would link the entire world in a huge network. Seidler felt, in what this strange youth was telling him, the interest that conservative business men sometimes feel in a venture that has its roots in imagination.

Now then, the young man explained, there were two systems of wireless telegraphy. One was the Marconi system; the other was the deForest-Freeman system. He modestly went on to set out, in great detail, just how and why his own system was superior to Marconi's. The business man nodded. DeForest said that he had a contract from the Publishers' Press Association to cover the yacht races by wireless, but that he had no money to buy the necessary parts with which to construct his apparatus. If Seidler saw fit to lend him the necessary funds, he had no doubt whatsoever that after the races his way would be clear. His "company" would be established then and Seidler reap his reward. The man said that he would think it over and get in touch with deForest.

To his utter amazement the very next day brought results; one thousand dollars in the treasury of the soon to be incorporated American Wireless Telegraph Company.

With this sum deForest went about financing the equipment for the yacht races. He was in a fever of excitement. The time was short before the day set for the races, but deForest thrilled to the idea of working under pressure.

The very first task was the construction of the Freeman transmitter. What Freeman had contributed to the company was merely an idea: an outline of a complicated transmitter that should have given great results. The plan was to build a direct-current generator of comparatively high voltage and pass the current into a bank of condensers in multiple. A commutating switch on the generator would throw the condensers in series after they were charged, thus yielding an output of twenty times the original voltage. The idea was excellent, but deForest was already greatly skeptical of the practical application. However, he soon found a machine shop, a little shop of which he wrote in his diary, "every inch of the place is familiar to me. It is a scene of the greatest activity I have ever seen. I spend here twelve hours a day supervising the construction of our apparatus, and my evenings, whatever is left of them after I have eaten my dinner in a lunch wagon, in designing and improving the parts. I spend a few minutes at most on my meals, and even while I am eating my mind rushes on — plans, changes, ideas. My sleep is ruined by the feverish excitement I endure. I am possessed of a kind of super-awareness of the importance of what I am doing and that only two more weeks remain in which to complete it. It is my chance, and I must not, will not, fail."

But this relentless young man had already failed on one vitally important point: he had neglected his physical self, had spent all his energy upon one machine, and let the other, his own body, get along as best it could. The second machine was soon giving way under the strain. Weeks of unremitting toil, bad food quickly devoured while his mind continued to work, sleepless

nights, these were the harbingers of a collapse. One night, a few days before the date set for the Regatta, the apparatus nearly completed, deForest discovered a terrific dryness in his mouth, a strange nervousness throughout his body, and a dull incessant pain throbbing through his head. True he had slept only a few hours for several nights past, and for days now he had barely nibbled at his food. But the extreme energy had always been there — until now. One of the men in the shop spoke to him.

"You look feverish," he said. "Can't last long like that. Better see a doctor."

DeForest scoffed at the idea of seeing a doctor. Nevertheless, as the day wore on these symptoms of physical disorder became more and more acute until the parts of the apparatus upon which he was working began to fade before his eyes. He was dizzy with weakness and exhaustion, but the challenging chorus kept ringing in his ears, "One more week, one more week." He kept at work for only one more hour before sinking off into unconsciousness. His co-workers had been expecting just such a collapse and immediately saw to it that he was sent off to a hospital. He revived as he rode down to the hospital, and a great sadness permeated his whole being, as he began slowly to realize he had been carried away from the excitement of the machine shop, doomed to lie in bed for days, perhaps for weeks, away from the scene of activity, away from all hopes of success. His illness was as nothing to him beside the overwhelming tragedy of failure, beside the nightmare of having to read the story of the races as covered by wireless telegraphy by one Guglielmo Marconi who had already achieved success, who had fame, money, power,

and who came to cover the races not across the threshold of hall bedrooms, machine shops, lunch wagons, rush work to put together apparatus, but as the head of a company under contract signed long in advance and with an apparatus that had been manufactured by many individuals rather than put together under the greatest difficulties by a very few. So the laurels would go to Marconi after all, all of them, while he, deForest, lay abed in a hospital, a stark and utter failure, living statue of defeat.

Then he closed his eyes and sank off again into unconsciousness, while the cab that brought him to the hospital rode on past many a scene of human activity and achievement.

THREE days came and went, but the anxiety that the weary young man anticipated was too blurred by fever to be very painful. When at last he regained consciousness and was able to glance curiously at the occupant of the bed next to his own, and realize that doubtless by this time the races had come and gone, the full measure of his defeat crept in. The doctor who had been tending him came in, told him an astounding bit of news; he had been ill for only four days. So the races had not yet come off. Three days left. A wave of joy swept over him.

"How soon do you think I'll be able to get up?"

"Not for some time. It will take you at least ten days to regain your strength."

DeForest hinted that he might have to get up before that.

"In that case," said the doctor, "we are not responsible for what may happen to you."

Next morning, deForest got out of bed and went back to work. There were just three days left before the races. Things were in great disorder at the machine shop. No one had expected him to return. He found to his horror that his apparatus had been abandoned in favor of more promising orders. What was the use in rushing the job when the thing would not be used anyway?

DeForest did not reply. He gave brusque orders that the apparatus was to be finished in time for the races, or it would not be paid for. Work began anew, long, relentless work. No matter what was accomplished, the chances were ten to one against finishing in time for the races. DeForest found he could not fall asleep until daylight. He had hardly dozed off before the street beneath his window was filled with yelling newsboys. "Extra paper! Extra — just out!" He hurried out into the streets, bought a paper and read to his horror the huge glittering headlines that told of the assassination of President McKinley. For days the tragic elements concerning the assassination assumed super-importance in the news. The International Regatta was postponed for six weeks, giving deForest time to complete his equipment, make trial tests, to work with intelligence and deliberation. He found that he could sleep at night, that his body was recuperating, that his faith was returning again.

VII.

THE day set for the races arrived at last. The apparatus had been moved from the machine shop and set up the night before in the tug anchored off Sandy Hook. Freeman and Smythe, amazed at deForest's successful arrangement with the Publishers' Press Association, completely taken aback by his having succeeded in raising a thousand dollars, and justly fearful that should the miracle continue longer deForest might indeed shoot ahead without them, had come on to New York. DeForest met them at the station and took them with him to help install the apparatus on the tug.

It was a misty night. The young inventor was weary. Nevertheless the excitement of the coming event was reflected in his eyes, his gestures, his voice, as with boyish enthusiasm he pointed out to the Chicago visitors where the various points of interest would be in the morning.

"That is the receiving station," he announced, pointing across the mists to a shack on shore, near the Sandy Hook Light House. "This is the starting line where the yachts will draw up."

He knew that the events of the following morning would make him, for the first time, an open competitor

of Marconi's; that the races would fling aside the curtain of obscurity that had so far hidden all his movements — his ideas, his experiments, his trials, himself — and his crystallized idea would stand on its own for the public to accept or reject. He was nervous, excited, sensitive to every sight and sound. The morning would bring climax. Many men waited half a lifetime or longer for the public to cast its jaded eyes upon them and their creations. DeForest was glad that his own climax was coming early in his life.

The mists faded from the dark court outside deForest's bedroom, and from the waters and shores of Sandy Hook, and morning came at last. A brilliant morning. Blue skies; a warm clear sky with a light breeze; sunlight.

Of the three who formed this "partnership" to launch an invention worked out on a two-by-four table in a hall bedroom, only the inventor himself was fully aware of the importance of the event that was about to take place. He caught the air of gaiety in the wearers of ankle-length dresses in pastel shades, the last word in sport clothes of twenty-five years ago, the sense of well-being and luxury that he, for instance, had never known. Here in this multitude of well-dressed men and women were men with sufficient money to launch his company, start a trial station, manufacture sets. Would none of them, looking curiously over the Publishers' Press tug on the deck of which stood the three inventors, realize what a treasure trove was there?

All of the multiple emotions the gala air of the races roused in deForest passed swiftly as he went to the top deck and began desperate work on the apparatus. The yachts were drawing up one by one at the starting line.

At any minute they would start out. DeForest threw a large switch on the left of the table. There was a hum. The operator pressed the key for trial. The result was a huge spark and a curl of smoke from the deck below. Then a thin constantly decreasing whine. The Freeman transmitter breathed its last before it had so much as put a single dot on the air. A desperate scurry followed. More life than the little tug had seen even in its days of storm at sea. A Rhumkorf coil, which deForest with pessimistic foresight had stored in reserve, was brought up from below and quickly substituted for the Freeman transmitter. The Leyden jars were connected to it and the key placed in the primary circuit with the storage batteries formerly on the Freeman machine to furnish the power. They had barely made the change in connections as the two boats, deForest's and Marconi's, cast off.

The press reporter in the pilot house of the tug called down the manœuvres of the two contestants to the Morse operator sitting at the key of the set. The first signals were sent off at the beginning of the trip. Suddenly the land station reported by signal flags that the signals could not be read. Pandemonium reigned in both the deForest and the Marconi tugs as the report from the land station continued "Signals confused. Can't read." Operators, inventors and assistants were alike horrified. The simple truth was that the incoming signals from the deForest tug were weakened and blurred because the Marconi signals from the second tug were "jamming" them. This was a point that neither of the wireless contestants had figured on. These were indeed the early days of wireless. The rudimentary principles of "tuning" were of course known, but there being only

two companies actively engaged in the use of the system, neither had thought it necessary to resort to the use of the tuning system.

But this fact did not come to light until after the races. Meantime, reports from the land station ceased as suddenly as they had begun. The two contestants continued to send their signals through the air, each believing that the interference had stopped and that now the signals were coming clear again.

The two yachts crossed the finish line, Sir Thomas Lipton's in the lead. The observation fleet resounded with cheers. The two tugs, Marconi's and deForest's, docked not far apart. DeForest, believing implicitly that his signals had been received, walked swiftly up to the land station and stuck his head into the window. The room was crowded with people, reporters and onlookers, laughing and talking. He walked straight over to the operator and inquired what the early reports about the confused signals had meant. The young man gave him the gloomiest news he had ever heard: Shortly after the last report the signals had faded out altogether. Both stations had been so hopelessly confused that the radio end of the trial had been kept up only for the sake of the onlookers. Both press associations, the Associated Press and the Publishers' Press, had used "wig-wag" code to get their report of the races. DeForest was horrified.

Newsboys were shouting "Extra." One of them approached the tug. DeForest leaped up, eager to avoid a continuance of this discouraging conversation, and bought a paper. There, to his amazement, he saw big

headlines over the reports of both the Publishers' Press Association and the Associated Press, reading "Received by wireless telegraphy from tug following the yachts." He called to Freeman and Smythe who came eagerly and looked over his shoulder. So the test had been a failure for both Marconi and deForest, but only those on the dreadful inside knew anything about it. After all, the press, in announcing the wireless feat as a special feature of their service, had assumed as much responsibility as the pioneers, and it was bound to make good. Such are the consolations of journalism.

DeForest was still penniless, still, in a physical sense, nowhere — and he knew it. But at least the public had been made aware of wireless telegraphy and of one Lee deForest as the inventor of a wireless system. He would have to go away somewhere and rest, for even now his hand was trembling from excitement and weariness. Then, when he returned, the sense of failure would haunt him no longer, and the fight would begin anew. He was beginning to understand something of what his father had meant when he asked, "Why do you choose such a hard way?"

PART FOUR

THE OTHER SIDE OF THE SHIELD

I

TIME and again deForest had been forced to leave some delicate experiment, into the making of which he was pouring his entire soul, to go out into the dust and the heat and the indignity of money struggles in market places to which he was alien. Always, however, in the back of his mind was the thought that if this commercial venture or that involved financing should succeed, he could achieve a certain amount of liberty for his questing. The love of up-to-date and last-minute laboratory equipment, expensive stuff at best, sent him into commercial undertakings of a highly speculative nature. Indeed at the very time when he was achieving reputation as an inventor, the business world was a confused battle of fiercely competing forces. "Laissez-faire" was the order of the day. DeForest himself asked for no quarter and gave none. He felt instinctivly, not that the world owed him a living in the parasitic sense, but rather that the financing of his undertakings was in the nature of a contribution to public welfare; that what he had to contribute would, in a measure, broaden and heighten the scope of mankind. He was chagrined and hurt time and time again to find that timid business men could not share in his abiding faith in himself.

Today, however, all that unhappy struggle for economic security, for peace and isolation in which to work out his ideas, for leisure to acquaint himself with the findings of his contemporaries in the field of science, is no more than the memory of a distressing dream. DeForest stands securely on his own financial feet, able at last to live the life of the scientist.

How, in one whose energies were poured into the making of apparati for successful wireless telegraphy, did radio come into being?

Even today, deForest finds himself from time to time confronted with this question. The word "radio" came into common use about 1910. It was used at that time to describe the travel of the human voice across space, symbol of speed and worldwide activity. Heretofore the term "wireless" had been in general use to describe both the travel of voice and the travel of signals across space without wire. After 1910 "wireless" was relegated to the older and now established field of wireless telegraphy, *i.e.*, the transmission and reception of wireless telegrams, cablegrams, etc., and "radio" became a synonym for the travel of actual words of the human voice, and music, across space.

And where does the audion come in? In 1905 deForest deserted the field of wireless telegraphy and turned his attention entirely upon the then difficult task of transmitting the voice across space. How the idea for the audion, which had first come to him in his hall bedroom in Chicago back in 1900, evolved gradually through the years 1903 to 1907, to its present place of undisputed supremacy, or, as Vanderbijh has said in his authoritative work on the "Vacuum Tube," "one of the very few fundamental inventions along with

Bell's telephone, Edison's incandescent lamp, and the steam engine of James Watt," is told in the chapters that follow. In the ultimate success of radio broadcasting the name of deForest came into its own at last. He assumed then his rôle of pioneer in the most logical field of invention.

But that is ahead of the story. DeForest and radio is one thing; deForest and wireless telegraphy another. Meantime, the story of deForest's place in wireless telegraphy is still to be told. We have left the inventor at the completion of the races with Marconi, with only the newspaper clippings of his dubious achievement in his pocket. Although it is a story concerned with machinery and business men and money, it nevertheless has all the elements of a Greek play, the slow rising crescendo, the final and complete disaster.

II

After a rest at New Haven, deForest returned to New York in the summer of 1901, and again rented the same small ill-equipped machine shop in the old Crushing Building on the Jersey City waterfront, and proceeded, in the face of the indifference of the investing public and of his own poverty, to erect the first wireless station in New York City. The future looked as gloomy as ever. Freeman and Smythe had both returned to Chicago. DeForest, alone in a hall bedroom in Jersey City, was faced with the problem of how to raise the necessary capital with which to carry on the business of the newly formed "DeForest Wireless Telegraph Company."

He sat down before the marble top washstand in this bedroom in Jersey City on a certain hot summer's night in 1901 and spread out before him the newspaper clippings telling of his work in Chicago and the transmission of the yacht race signals. Next morning, having arranged the clippings in the order of their importance, he set out for Wall Street and started a quest for capital that meant not only attempting to sell business men an idea but also to acquaint these very men with the exciting possibilities of the science of electricity. It

meant educating people who did not want to be educated. It was heart-breaking work. In the process DeForest got to know doormen, office boys, elevator men, secretaries, and a group of cynical people vaguely called "assistants." So the days passed. Whenever he did manage to see one or another of the top men of Wall Street, he found that the idea of wireless telegraphy met with complacent contempt.

At last, after countless rebuffs, he ran into a promotion man, one "Peewee" Snyder, who had seemed interested in the possibilities of wireless during the inventor's earliest days in New York. Snyder became his financial agent and together they managed to raise several hundred dollars from a group of two or three people who did not quite know how or why they had invested in the hazardous venture of wireless telegraphy. DeForest began to understand that these were not the proper financiers for such a new and untried project, but once his trial station was functioning properly, he reasoned, more imaginative and generous capitalists would surely appear.

These few hundred dollars went far. The bitter experience of the yacht races had not been without its lesson; he had seen the difficulties to be encountered in using a spark coil for transmission. Now he began at last what he had tried to do in Chicago with Freeman against the latter's advice,— to work out the details of a transmitter using alternating current. He ordered a transformer and motor generator, which apparatus alone cost upwards of three hundred dollars. A scientific instrument company furnished the Leyden jars which were to be used as transmitting condensers. The trial station in Jersey City began to function at last.

The incident itself seems small, but its scientific aspect is noteworthy. The transmitter used in the trial station in Jersey City was the first wireless telegraph transmitter to use alternating current as a source of supply. It was a great step forward in the art of wireless telegraphy, but it was not the first idea that deForest had held dormant in his mind, awaiting only the detail of money to put it into operation. In fact the whole of his marvelous contribution to the technological advances of America has been a process of slow and often bewildering upbuilding as he all too tediously gained the necessary funds and assembled his experimental equipment.

For instance, even at that time he planned to develop his idea of "wireless telephoning" as soon as ever he could afford the necessary implements. Indeed the original entries in his note books looking toward a wireless telephone are dated August 21, 1900. At that time he wrote: "Hints for wireless telephony, sending end." Here followed an amazing group of drawings which crudely anticipated the telephone radio transmitter as we know it today.

But these were ideas that deForest was forced to put far behind him. Economic freedom was nowhere in sight. Once the trial station was established in Jersey City and the machinery paid for, fresh funds were needed to keep it going. After several conferences in which it was found impossible to raise more money, a new system of finance had to be tried. It was suggested that some first class promoters take up the sale of the company's stock and try to raise the money from the public at large instead of continuing the futile and time

wasting attempts at finding one particular man or a group of men to back it.

Meantime new difficulties arose on all sides. DeForest was driven to write: "Once let me get the power, once let me be the dictator — and I will dictate. Then and only then may I hope to succeed, free from the shackles and impediments of those who surround me. Never was one so tied and handicapped in the promotion of one of the most logical business ideas that have ever appeared before the microscopic mentalities of the men to whom I am forced to appeal. And all of them, if they only knew it, could make for themselves a place in the history of communication as well as great wealth. I am left to do it all, to be diplomat, inventor, executive, errand boy. I draw five dollars a week if I am lucky. Three months of this have shown me the measureless disparity between the inventor's and the investor's point of view."

This while the fight to raise money through selling stock went on; and while Wall Street turned a deaf ear.

III

In November, 1901, deForest had met a romantic figure, a man who had color and dash, humor and money, who came like a flash of brilliant color into the monotony of the Jersey City waterfront. His name was Abraham White. He had a few years earlier enjoyed a most miraculous streak of luck as a "postage stamp bidder." With no money in his pockets he had successfully bid for several million dollars of United States bonds under Cleveland. Whereupon, with colossal nerve and an inimitable courtesy, he had called upon Russell Sage and induced that notable gentleman to finance the bid. White had come out of the bidding a winner by $100,000. Here then was a successful speculator, a man who could make up his mind quickly — and gamble.... In a word, just the kind of a backer deForest had been looking for. In one afternoon he became completely converted to deForest's idea of wireless telegraphy.

"You must need money to carry you along," said White. "Better take this until we make further arrangements."

He held out a hundred dollar bill, the first deForest had ever seen. A plan was immediately drawn up and executed. The American DeForest Wireless Telegraphy

Company was organized and incorporated under the laws of the State of Maine, with an authorized capital stock issue of $3,000,000.00, the small parent company organized by deForest, Manning, Stires and Seidler the preceding summer being bought over with its patent rights, inventions and equipment extant. An experienced salesman named John Firth who had originally brought deForest and Abraham White together, now became interested in the company to the extent of bringing all his financial experience to its aid. Barbour, deForest's class-mate at Yale, bought out Seidler's share in the company, thus eliminating another objector. So the business began to run smoothly. The public began slowly to turn with some interest towards this newest of scientific wonders. Stock was sold. DeForest raised his salary to thirty dollars a week, his "high-water mark" at that date! He even began to buy things for his Jersey City bedroom.

His attention immediately turned to the scientific and technical problems forever present at the new transmission station in Jersey City. For demonstration purposes a receiving station was installed on top of the Manhattan Life Insurance Building at 60 Broadway where White had arranged for deForest to have a tiny room in the dome. Here he set up his receiver and test trials were made. For days, deForest and his younger assistant, Walter Stryker, worked unceasingly — but the signals would not come through. At last seeing the futility of their efforts, in desperation they moved their receiver to the Whitehall Building at South Ferry. Straightway the Jersey City signals came booming in. With the inevitable instinct of the scientist, curious to discover what had been the reason for the failure, de-

Forest went back to the old station, presumably to collect remaining apparatus. As he prowled about his eye fastened upon a certain greenish deposit on the edge of the dome over which he had erected the antennæ. The truth flashed through his mind. Copper! It had absorbed all the power from the receiving antenna. He had gained a valuable bit of information.

New problems followed. There were frequent breakdowns at the new location. At that time the people engaged in the manufacture of transformers, generators, and condensers had little or no experience with the surges of high voltage involved; hence the motor generators were constantly breaking down their insulation. Leyden jars, not very well made, were the only available form of condensers. White would often bring prospective investors to see demonstrations, only to have the equipment break down in the process. Upon these occasions White's inimitable wit became balm to the disappointed business men. They agreed to return for another demonstration another day.

Then White came into more money. Immediately he erected a pent-house for deForest on the roof of the building at 175 State Street, a little wireless hut made all of glass and steel. The transmitter was immediately moved from Jersey City and installed in the new wireless station, the first constructed on top of a tall building, and a second transmitter and receiver were installed at the old Hotel Castleton in Staten Island. This was the first time deForest had had a chance to try out a double wireless set. Countless tests were made from the State Street Building to Staten Island and back again over seven and a half miles. Service was finally established only to be frequently interrupted by the breakdown of

the transformers. Every Saturday afternoon, the company's funds having been completely absorbed in equipment, the loyal wireless operators, Harry MacHorton, "Barney" Barnhardt, "Pop" Athearn, and Harry Brown, together with "Doc" deForest, as his men already affectionately named him, would shoot crap or match to see who would hock his watch to stake the group over the week end.

On one momentous day White announced that he was bringing George Westinghouse up to the roof. It was a hot day. The sun beat down through the glass walls of the little wireless house as deForest and his assistants worked hard to complete their tests before the arrival of the august Westinghouse. The great captain of industry arrived at last. The signals were sent out. The answers came in swiftly. It was a perfect demonstration. Westinghouse said that he would have to think the matter over carefully before he made up his mind. His decision finally reached the deForest group. Westinghouse was not interested. He could not see the importance of wireless telegraphy from a commercial point of view!

Notwithstanding such terrific discouragements, these demonstrations began to bring money into the company's treasury. In the course of a few months, as a result of the constant repairs, notes covering the method employed and the amount of success it achieved, deForest finally evolved a formula of construction which included a fairly dependable transmitter. In his every spare moment he set about experimenting with other and more perfect means of detecting the Hertzian waves. A new method was evolved to take the place of the outworn Sponder: a simple object consisting of two

large aluminum wires with roughed upper surfaces, across which a needle was laid. When used in connection with the telephone receiver, this simple device would detect the signals but would automatically restore the conductivity of the telephone receiver at the conclusion of the high frequency train. In other words, an automatic decoherer.

Then wireless got its big push forward. Shortly after the perfection of the device described above, de-Forest was invited to install on a War Department tug boat, the "Unique," and to erect for the Signal Corps a land station on the Rhode Island coast at Fort Mansfield and another at Fort Wadsworth. This was in the summer of 1902. War Department officials had finally come around to a recognition of the importance of wireless telegraphy, and wanted accurate information as to just what might be expected of this new marvel in time of war. DeForest went down to the East River and equipped the tug with his transmitting apparatus. Two expert operators were hired to read the code. DeForest himself remained at the land station, supervising the work for three days and nights of unremitting toil, while suffering the most frightful hardships. The wireless hut was within twenty yards of the big guns, and when the cannonading of the mock warfare between the Army and Navy began, deForest soon found that he would have to suspend his receiving apparatus by strings from the ceiling of the shacks to prevent its being destroyed by the terrific explosions. Nevertheless the tug flashed back its reports to Fort Wadsworth and Fort Mansfield on shore, marking the first use of wireless telegraphy for military purposes.

During the early morning of the first day of the test

deForest was alone. The wonder of the thing he was doing dawned upon him as he watched the play of light and shadows on the water, for in his diary he wrote:

"I am sitting in our little station here, telephone to my ear, awaiting a message from our tug boat lost somewhere on the broad waters of the Sound. Wherever it is I will soon hear its mysterious call speeding over waters and islands — invisible, bodiless — yet awakening responses in this tiny tube which rests on the case before me and listens always. It is a marvelous thing, this etheric language, and when not too much engrossed in the mechanics and business of it all, my mind is lost in admiration of its infinite mystery."

Throughout the tests deForest and Athearn and Horton kept in touch with the movements of the "enemy's" ships at sea, securing perfect coöperation between the land forts and the Signal Corps craft spying on the fleet. And from this point and date his progress became consistent. A very short time after an official report of the trials was made deForest was called to Washington and asked to manufacture several wireless sets for the Government. Another station was installed at the old Navy Yard at Washington with a companion installation at Annapolis. Before this the Navy had used only the clumsy and intricate German apparatus. Christmas week 1902 two-way communication was started and was perfectly maintained. During the winter of 1902-03, orders for equipment began to pour in and the small Jersey City plant was turning out all the apparati it could produce.

These installations for the Government now became deForest's laboratory pro tem. It was a laboratory without walls, however, in which the public could watch his

every manœuvre. Although it interested and even fascinated him, and although he recognized its inestimable value for the final acceptance of wireless telegraphy, he was still the scientist, longing anew for the isolation and at last the satisfaction of unnoticed experiment beyond the walls of his own laboratory, for new ideas were teeming in his brain.

The urge for a decently equipped laboratory of his own had been his ever since he left Yale. Now deForest seized the opportunity of temporary financial ease to open a new laboratory on Thames Street, New York City. But it was pathetically ill-equipped. The stations installed for the Army and Navy attracted the attention of new investors. During the cessation of immediate financial troubles deForest bought and worked over new instruments — put new ideas into practical form.

It was in this Thames Street laboratory a little later that a new wireless detector was created. A fine platinum wire was flattened out and sealed in a small tube. Then the end of the tube was broken off and ground down so that only a small edge of wire was exposed to the acid in the tube. The glass tube was mounted on a brass shank, which could be screwed into a holder which in turn was suspended over the lead cup holding the acid. The invention was the work of deForest's loyal and resourceful assistant, Clifford D. Babcock, who was tireless in his efforts to carry out every suggestion of his chief. This little device, mounted on a rubber base to minimize vibration, acted as a second electrode to the detector. Actually it was based on the original discovery in 1899 of Professor Pupin. It proved to be a very reliable type of electrolytic rectifier. The Navy found these little "Spade electrode" detectors

exactly suited for their purpose and ordered them by the hundreds.

With practical success achieved at last, patent complications arose. It must be remembered that the wireless stations installed thus far and for some time thereafter were all using deForest's alternating current transmitter and the electrolytic detector. Now a long patent suit covering the electrolytic idea was started by Professor Reginald Fessenden, well-known inventor, which was not finally adjusted until 1906 when the deForest-Babcock electrolytic detector was declared by the Federal Courts to be an infringement upon Fessenden's patent. Thereafter the company used the "carborundum detector," the invention of General Dunwoodie of the U. S. Army, then a Vice President of the American deForest Wireless Telegraph Company, and later used the "audion detector" in 1905-06.

IV

One day early in 1903 there walked into the deForest office a newspaper man, a representative of the Providence *Journal.* He had come, he said, to ask deForest if it were possible to erect wireless stations at Block Island, far out on Long Island Sound, a summer resort, where many resident of Providence spent their vacation. News of the doings of these people, said the reporter, was slow in reaching the *Journal,* and wireless reports of their activities would give his paper a beat on all other New England periodicals. DeForest gaped at the man in amazement. Here in fleshly form was the realization of his dream to apply wireless telegraphy to the needs of journalism. This *Journal* man was almost too good to be true. Before he had left a contract was signed which called for a wireless station at Block Island and Point Judith, flashing back and forth news of the mainland and the island.

This was in the Spring of 1903. But summer static arrived to cause havoc with the arrangement. A violent thunderstorm blew down the high mast erected on Block Island. Fortunately deForest was on the spot at the time. Quick-wittedly he hooked up his receiving apparatus to the telephone line extending straight across

the island in the direction of Point Judith and to everyone's astonishment the signals from Point Judith came in with far more clarity and precision than over the now destroyed antennæ. It was this ill wind which blew for deForest the discovery of the directive flat-top antennæ of the type that is now employed at all the large trans-oceanic stations. Although the lofty vertical antenna was again installed, the telephone line was cut in whenever atmospheric disturbances occurred and was effectively used.

Reporters swarmed around the receiving station at Point Judith and every story they wrote boomed the stock of the Wireless Telegraph Company.

The publicity had its repercussions in the War Department. The fleet was again about to hold manœuvres off Fisher's Island in Long Island Sound. Naval officers now were stirred by the idea that their vessels also could keep in touch with the shore by means of wireless telegraphy. They turned to the only man in the country who could provide these means on short notice. DeForest as usual was ready for the emergency. His old station at Coney Island did yeoman's work in keeping in touch with the far-ranging ships of the Navy and impressing the most hard-boiled of the skeptical sea-dogs on their decks.

Out of all this welter of diversified activities came to deForest a new, a golden opportunity. It was his chance to repair the damage that had been done to his reputation by his failure to report the yacht races for the Publishers' Press Association of two years ago. Again the indefatigable Thomas Lipton was challenging America's supremacy on the seas, and again deForest was called on to report the races by wireless. However, on

this occasion deForest came off with flying colors. Although he had rivals in the shape of the Marconi company and another corporation, both of which justly attempted to interfere with the transmission of his signals by monopolizing the ether, deForest by the aid of his old Wehnelt interrupter of Armour Institute days, hastily assembled throughout one night and installed on the tug by daybreak, made his signals readable through the clamor of his rivals.

Sir Thomas Lipton was so pleased with the reporting of the yacht races and the constant wireless service rendered over the period of five weeks from his palatial yacht "Erin" while in New York waters that he caused the General Postoffice of Great Britain to send an invitation to deForest to visit England and demonstrate his ability to establish a continuous service between Holyhead, Wales, and Ireland. DeForest was delighted. This was his first chance for an overseas voyage and he made the most of it by setting up with his friend Horton the most elaborate and ingenious devices that the Atlantic travelers of those days had ever seen. There was no lolling for him in the deck chair of the steamship. Every day of the voyage he and Horton were busy with their wireless tinkering.

In London deForest, with only two days to see the city, made arrangements with the London representatives of the deForest company for setting up a sending station above the Holyhead Light on top of a cliff which rises six hundred feet out of the sea.

Horton went across the channel to Howth, near Dublin, where he in turn erected his antennæ. Back and forth across the Irish Sea with the help of a couple of second-hand gas engines which deForest had purchased

in London there flashed, for the first time in wireless history, high-speed Morse telegraph communication between Wales and Ireland, in the efficient, dashing American telegraph style unknown in Europe.

But there followed ridiculous diplomatic manœuvres involving nationalistic prejudices as a result of which deForest and Horton started back to New York. A fellow-passenger, Captain Lionel James, was a reporter assigned to cover the impending conflict between the Japanese and the Russians. DeForest and James struck up a great friendship and before long deForest had completely convinced the reporter of the necessity of covering the Russo-Japanese war by wireless telegraphy. This early convert made for himself and for his paper a reputation for "spot" news which is still untarnished. By terrific pressure deForest was able to despatch his trusted operators, "Pop" Athearn and Harry Brown, to arrive a short time before the opening of the conflict. They were barely able to erect in time a shore station at Shantung, China, using all the available bamboo in the neighborhood, a sending station which reported to the underlying credit of the London *Times,* the New York *Times* and the American deForest Wireless Telegraph Company, the whole story of the Russo-Japanese Naval War.

Meantime, in his first inland wireless installations, one at the tip of Lake Erie near Buffalo and another at Cleveland, deForest was breaking news records for long distance overland transmission. He had in fact bridged 180 miles of frozen ground and ice between these stations, the greatest overland distance ever covered by wireless telegraphy up to 1904.

More than that he was making changes every day in

the transmission and receiving equipment, changes that involved important steps forward in the art of wireless telegraphy. For instance he had now installed for the first time complete tuning arrangements at the receiving ends, consisting of two double tuning coils in electromagnetic relation, which device constituted the first real adaptation of adjustable tuning to commercial radio apparatus. The idea of tuning was by no means novel. Hertz himself had touched upon the principle of tuning in his classical experiments, but it remained for the more modern-minded engineer, dealing with everyday problems of electric waves in wires, to discover the inestimable value of the adjustably tuned circuit, and to put Hertz's principle into practical application.

And so at last the inventor felt the glow of victory, an all too temporary realization of his pioneering dream. The years 1904-05 may be said to be the high water mark of deForest's association with wireless telegraphy: surcease from financial struggle and public recognition of his work. The newspapers carried frequent stories describing deForest's rapidly succeeding works. Investors read and invested anew. It seemed that the "Wireless Wizard," as the press liked to style him, at last came into his own.

The Spring of 1904 brought with it the World's Fair, this year to be held in St. Louis. DeForest and White had long anticipated having an exhibit and stations at the fair. Concession space was granted. The inventor and his assistants, their energy renewed in the face of their recent victories on the Great Lakes and in the Orient, went on to begin the erection of sev-

eral stations. The first wireless transmitter, on the tallest structure on the exposition grounds, towering high above the tops of all the buildings, was installed on the central lever of the observation tower and thoughtfully housed in glass so that visitors would have a complete and perfect view of all the working parts in actual operation. DeForest's imagination was not taxed in the production of this unusual exhibit, for he knew well the importance of answering the eternal question, "How does it work?" The second station, involving a far-flung power goal of twenty kilowatts, was placed just next to the Boer War exhibit. The work of installation was not without its disappointments, but the deForest crew of workers were by now case-hardened. In September of 1904 this record-breaking station was opened, and constant wireless telegraph service was maintained uninterruptedly between Chicago, Kansas City and Springfield during the whole remaining time of the Fair. A record of 300 miles for the dependable transmission and reception of overland messages was easily established.

Besides this first regular publicly patronized overland telegraphic service in the world's history, deForest had made a contract with the St. Louis *Post-Dispatch* to furnish that paper with press reports of the daily events at the Fair. It was not the only novel item in the deForest demonstration of the progress of wireless telegraphy. Housed in the Transportation Building was an automobile, latest 1904 model, equipped with a complete portable transmitting station. Small wonder indeed that the awards went to the deForest exhibit.

DeForest himself, although much of his time was consumed in general supervision of the operation of the

Fair stations, found time to drink deep of the comfort and the victory that was his at last. He lived well, had stimulating working surroundings, and heard every concert and musicale that the Fair program offered. The Exposition grounds were thronged with his contemporaries in the field of electricity, engineers and scientists with whom he could compare ideas and sharpen wits. He marvelled at the changes in the world since that other World's Fair he had attended in Chicago just eleven years ago. Pleasant reminiscences filled his mind. Eleven years ago, in 1893, he had pushed sightseers up and down the Fair grounds. Then he had stopped at his first sight of a steam hammer, to marvel at its hugeness and power.

Today, just eleven years later, he was attending another World's Fair. It was of greater stature and he was in a different capacity, that of scientist and inventor, contributor to a swiftly changing universe. Now he felt the ground under his feet, ground that far from holding him, only forced him on to greater distances, among newer ideas. From time to time he would watch with interest the sun-burned youths pushing new sightseers to more marvelous sights, and wonder how many of these young men, although apparently only menials, were on their way to great things. And a sense of the power and the drama of the creative instinct would come upon him anew.

V

It would be useless further to detail the wireless stations set up by deForest and his steadily growing corps of able assistants, each station representing a new triumph for the novel idea of wireless telegraphy, each message sent and received turning the attention of the investing public to wireless and dissolving at last the thought that deForest was engaged in a hazardous venture. But it would hardly be fair to pass on to the final chapter of deForest Wireless without explaining some of the more permanent aspects of the inventor's life and works during his years in Chicago and later in New York.

These years completely cover deForest's association with wireless telegraphy, from the time of his arrival in Chicago, where he first worked out his idea for a new detector for wireless signals in his hall bedroom in 1900, through his amazing achievements, on up to his final desertion of the wireless telegraph field in 1906, and the alliance with the newer idea of wireless telephony, an art which led him almost directly into "radio" and "radio broadcasting."

These eight years constitute a cycle in the inventor's life. They are years fraught with more actual achieve-

ment than the whole lifetime of many an equally worthy and valuable creator in the realms of science and invention. They brought two vital aspects to the future work of Lee deForest: first, an unending loyalty on the part of his associates, a loyalty that gave him a new basis of action, and proved to be at times his only remaining weapon against a menacing fate; second, recognition on the part of scientists and engineers the world over of his invaluable contribution to the art of wireless telegraphy, a recognition that seemed indeed to foresee that here was a man who in one manner or another, through one idea or another, would help bring the four corners of the earth closer together; and through some final and inevitable miracle of his brain and hand, push forward with a decisive thrust the difficult art of technology.

Neither of these two was without reason, though the second is more easily explained in simple fact than the first. From the days of the earliest of deForest's wireless stations, when he had little or no money to pay employees, he found small difficulty in getting Western Union operators, capable men assured of a good steady salary, to come with him for a weekly pittance that sometimes was not there. There was something about deForest's venture and deForest's personality that made these men want to work with him against the greatest hardships, something akin to the feeling that makes men long to fight in war under a fearless general. During the Spring of 1903, when all of Sir Thomas Lipton's private business and Associated Press reports were transmitted by deForest wireless, there was Thomas Vosburgh and "Sunny Jim" Eastman, both men who could easily handle thirty and forty words a minute, a speed far beyond that of the English and German

operators of the time, who had come with deForest "for better or for worse."

In 1906 at the triumphant completion of the installation for the U. S. Navy of their five largest wireless stations in the world, deForest wrote a letter to one of his closest associates in wireless, Frank E. Butler, which may explain something of his generalship as well as his suffering. It reads:

"For tedious months away from home and friends, in climates scorching and unhealthy, deprived of all usual comforts of life, tormented day and night by insect pests, distressed but not baffled by static unknown to any other wireless workers, delayed month after month by breakdown of Navy apparatus, continually called upon to make repairs, often without proper tools, facing sceptical criticism, surrounded by hostility, open or concealed, on the part of officials from whom we had every reason to expect coöperation and interest — you have stuck to your posts, have triumphed over one difficulty after another, have forced new secrets from nature, and have by your tenacity, patience, and skill accomplished your ends. You have won at last an unwilling acknowledgment of the success of the system from the entire Naval Department and set a new standard in the art of Wireless Telegraphy."

DeForest was quick to cheer but slow to criticize. And above all he was ever eager to share the honors of his labors with those who worked with him. In the spiritually damaging climaxes which came all too unfairly as a result of his interest in his work rather than in shrewd business manœuvring, it was this very loyalty on the part of his men that held him up and kept his

faith, his seemingly endless faith that had buoyed up many another in a crucial moment, from threatening dissolution.

THE second element, the recognition accorded him, depends in a measure upon a still more mysterious force which has to do with brain rather than with personality. It involves the story of how he worked in his hall bedroom and later in the laboratory of the Armour Institute on a new type of detector for wireless signals. At that time Lodge, Slaby and Marconi, men who had begun earlier and gone further than deForest, all used the Branly coherer: a small glass tube filled with silver filings. It had the property of cohering when high frequency electric waves passed through; it allowed the current to pass from a local battery to a relay of some sort. DeForest in 1899 determined to find something which would respond to the wave and then automatically go back to its original resistance condition.

We have seen how from the beginning of his work in his hall bedroom he worked out and patented first one idea and then another: the "Sponder" first; next the use of the telephone receiver as a receiver for wireless; and third, the development during the years 1902-06 of the alternating current generator and transformer for Wireless Transmitter and also the "two-coil" and "three-coil" slide tuner for receiving, as well as the "loop antennæ" which represented a great improvement over the straight antennæ which had been used heretofore everywhere in the United States and Europe.

These important divisions represent merely the broad outline of deForest's wireless inventions. It must be

remembered that his wireless installations during these years were in the nature of a laboratory, everything to be "tried out and tested," new discoveries to be made each day. It would seem to have been impossible for deForest to have fastened his restless inventive mind upon any project without immediately seeing several ways out; and the project was no longer an idea: it was an actuality, an engineering feat to be accomplished, new machinery, new devices, new tools. His genius was taxed and it made answer. He had been constantly taking out patents on the various ideas he developed, some of them entirely theoretical which did not come into practical use until years later, after new machinery had been invented to make them possible; others quite practical and immediate, covering the difficulties he solved in transmission and reception. This large group of mechanical applications was directed toward the amelioration of seemingly impossible defects in operation. A glance at these ideas will suffice to show deForest's boundless intellectual energy that contributed largely and generously to the science of wireless technology.

The loop antenna, patented in 1902, was indeed a pioneering patent, that was far in advance of the art of wireless or "radio" of that day. This patent was possibly the first commercial adaptation of the loop antennæ. One of the interesting features in these patents is the fact that many of them are just beginning, even at this late date, to find important applications in new fields of short wave work, a field whose development still promises great results. Another patent, applied for in 1902 and issued in 1903, covered the present reflector wires placed at the rear of an an-

tenna to direct its radiation, along somewhat the same lines as the system used in the Marconi beam transmitter. The underlying principle was not original with deForest. It represented an adaptation of Lecher wires for receiving, and was known long before deForest worked it into the practical form contained in the patent.

In the more mechanical branch of inventions was a joint patent by Lee deForest and Walter Clark. Many a time careful plans in the station were swiftly mutilated by a sleet storm in midwinter that broke down the aerial with a load of ice. Now then, the question was how to keep the wires warm enough to prohibit the formation of ice. He resorted to a "step-down transformer" that threw the whole supply of the generator directly into the antenna. Proof of the merit of this system lies in the fact that it is now used in various of the large trans-Atlantic stations, for it does away with one of the most obvious and destructive problems in wireless.

Another difficult problem that baffled wireless operators and engineers was how to control large currents from the operator's key. Faced with this constant problem, deForest patented the first of a great number of control systems. Just as no controlling device is ever the last word in machinery, for each day new and larger amounts of power are released from the earth and from the air, so deForest constantly changed his method of control as the art of wireless made new advances wherein it was found possible to use larger and larger amounts of power. This power, of course, had to be instantly controlled. Sometimes the transformer balked. New devices for making and breaking the current came

into use. But each device was another item in the already complicated station in control of a single operator. DeForest faced the problem of how to keep down the size of the station so that it could be efficiently handled by one man; in other words, how to combine parts and do away with other parts; how to simplify the wireless apparatus.

Various original pioneering devices were patented, some of them having been rejected as wireless progressed, others remaining in use even until today. For instance the original patent on the beam transmitter shows much the same device as that employed today. Altogether deForest's wireless patents comprise everything from an oil break key to synchronous telephony. In the five years of his close association with the problems of wireless, thirty-four patents were granted him. The most modern-minded radio engineers and inventors, facing the future of radio, are grateful indeed for the far-sightedness of deForest's inventive genius during those early days of wireless.

VI

These are the more abiding aspects of deForest's early achievements. They are in the nature of tried and tested truths that the passing of a quarter of a century has served to brighten rather than to obscure. Meantime the hostile onrushing fates that would have destroyed many another less strong-hearted than Lee deForest, were beginning slowly to surround him, belittling the work of his brain and putting to shame the high hopes of the individual.

The climax of the wireless saga is expressed upon a sheet of yellow paper, the stationery of the American deForest Wireless Telegraph Company, of which Abraham White, who in the beginning had promised such courage and understanding, was still president. It is in the form of a letter written by deForest to the directors of the company, and it is dated November 28, 1906. Although it reads simply, with deForest's characteristic straightforwardness, "I herewith tender my resignation as Vice President and as Director of the American deForest Wireless Telegraph Company, the same to take effect immediately," it is a human document in the life of the inventor, for it represents the end of the first cycle of his life as well as his first

achievements in science, and the end of his young manhood and his intense creative work.

The notation beneath the letter, written in deForest's own hand, tells something of the tragedy of the experience. It reads: "This is the funeral of my first-born child! This is the finish to the hopes and efforts which have made up my strenuous life for the past five years. That which I had wrought with pain and ceaseless endeavor to make grand and lasting and triumphant — is prostituted, sand-bagged, throttled and despoiled." This would seem to be the end of the story, but at the very edge of the page, written in a darker ink than that used for the rest of the letter, is a thin line, "But my work goes on while I live!" The future chapters of the biography will reveal something of the power behind that battle call of Lee deForest to himself.

Just what happened was this: After the World's Fair in St. Louis there was great business on hand. The Navy was about to award five contracts for stations to be erected in the vicinity of the Gulf of Mexico. DeForest called his staff into conference, with the result that a month later the contracts were awarded to the deForest company for the stations, thus setting aside the bids of the other three contestants, the Telefunken Company, the National Electric Signalling Company and the Marconi Company of America. The heartbreaking experience in erecting these stations for the Navy has already been briefly but graphically pictured in deForest's letter to Frank Butler. The whole winter and Spring of 1905 was consumed in erecting and putting into operation these five stations, at Pensacola and Key West, Florida; Guantanamo, Cuba; Colon, Isthmus of Panama; and San Juan, Porto Rico.

In 1905 came the tragedy. Abraham White, president of the company, viewing deForest's hard-earned success, decided that here was a time for a huge drive in wireless, a drive that would put before the eyes of prospective investors something glittering to behold. DeForest, his mind filled with the exciting scientific aspects of wireless after the baffling but victorious setups for the Navy, returned from England to the home office in New York in the summer of 1906 to find stories running in the daily papers to the effect that White had obtained control of both the Marconi Company's stock in this country as well as that of the deForest Company, and intended to amalgamate them into one huge corporation. As to the truth or fiction of this idea, the next morning the Marconi Company came out with a signed statement to the effect that Mr. White had not gained control of any Marconi stock whatsoever. But the report was the harbinger of still more audacious promotion schemes that had already been put into effect while deForest was, or so he thought, accomplishing great things for the company.

DeForest heard and saw — and made plans for withdrawal. The company was already in serious financial difficulty. In place of the success that was justly due and for which he had striven so long and in the face of such hardship, a crash was coming, a crash that involved both his personal fortune and the success of his inventions. As he took in the situation, a bitterness for the first time crept into deForest's brain, a bitterness that went too deep for him to humiliate himself further by fighting over the spoils. Instead of carefully laying his plans for salvaging from the company what right-

fully belonged to him, he wanted only to get away, to get out, to get on. He simply refused to have anything whatsoever to do with the new speculative schemes of the promoters and voluntarily gave in all his stock, holding only the rights of his Audion Patent Applications which were then pending, and the absurdly modest sum of $1,000 in cash. . . .

What followed is indeed interesting. For the first time the officers of the company were ashamed before this great man of science, whose interests were so deep in the scientific end of his work that he had asked for almost no personal reward. They promised him at least the $1,000 for which he so modestly asked, and turned over to him the pending applications for patents on the Audion which, incidentally, they thought quite worthless. It is hardly to be wondered at that promoters whose understanding of even the financial significance of these Audion patents was so limited that they were glad to give them back to deForest, inevitably must have brought his beloved company to disaster.

The final incident which marked the end of deForest's association with wireless telegraphy, the present gigantic industry for whose establishment the pioneer inventor sacrificed so much, is worthy of mention. Although it is seemingly unimportant, involving no more than five hundred dollars, its very pettiness the more clearly defines the humiliating position of this man of science.

Too oppressed by the collapse of his company to deal personally with its wreckers, deForest retained a lawyer to draw up the final papers, the assignments and the claims. The executives of the company kept their word and turned over the promised thousand dollars

cash to the lawyer, as well as the rights to the Audion Patent Applications, accepting his receipt on behalf of his client. Accordingly, after the papers had been drawn up, deForest, who was now quite without funds, called upon his attorney to collect the thousand dollars and to pay the lawyer's fee. Whereupon the attorney handed over the papers together with a check for a sum of money representing the net commercial value of these years of youth and struggle and achievement, $500. Dumbfounded by this new evidence of unscrupulous dealings, deForest was exasperated almost beyond words. He flared up anew, and for the last time, against this almost inhuman pettiness, and demanded the rest of the cash that was rightfully and legally his. . . . Only to be informed that this $500 had been retained by the attorney as his fee, and that if he didn't like it the gentleman would take it all!

VII

So Lee deForest, engineer and inventor, who had made American wireless telegraphy lead all the world, left the office of this successful Wall Street lawyer, with $500 in his pockets, and a paper assigning to him the rights on the seemingly worthless and still pending Audion patents! He had come a long way with his ideas. From an obscure boy in a prairie town he had risen to join the ranks of the great inventors of the world. Only to have a clever lawyer come off the victor by five hundred dollars.

It was the summer of 1906 and deForest was a man of thirty-three years, living in a modest apartment on Riverside Drive in a few comfortable but unpretentious rooms. He was living a dull and loveless life from the ordinary human point of view which cannot contemplate the whole of a man's energies being poured into a great work.

In the street outside the building that harbored the lawyer, he stopped for a minute to think of where he would go and what he would do. He walked to a newsstand, purchased an evening paper, and searched for items under the heading "Music." No concerts to-

night. Not a symphony in town. He dropped the paper carelessly in the street.

Instinctively he made his way to his laboratory in the Parker Building, loosened his coat, for outside, whatever else was happening, it was a hot summer's night, and faced a familiar and somehow comforting sight. DeForest's laboratory in the Parker Building, by contrast to the shining, well-equipped places of experiment that today inspire the men of science hired by the great power companies, was not pretentious. It was a good-sized laboratory room, of about the same proportions as the extra-sized living room in expensive New York apartments. It had two windows facing north. On another side towered the Metropolitan Life Building. For furnishings it had two tables, a few uncomfortable chairs, a work bench. For equipment, the large high-frequency generator which had been made to order and with which deForest hoped to establish wireless telephone transmission (his next task), storage batteries, the ordinary dry batteries, and an old Columbia phonograph with a few records. Although the appearance of the laboratory would lead one to suspect the inventor had been using the phonograph as a means of relaxation, he did not approach the phonograph but sat down instead upon his work bench. The truth of the matter was that the phonograph had been used for a very different means than relaxation: deForest, besides transmitting wireless signals, had been hard at work upon various devices which would one day transmit the human voice across millions of square miles. And the phonograph records had been used in his experiments.

Even now, in spite of all disappointment, in spite of the bitterness that even against his will was creeping

into his thoughts, deForest was thinking of another idea, born in his brain for the first time in his hall bedroom in Chicago, worked over and labored for during these long years whenever he could find time, and already at that point of development where patents were pending: the Audion.

Now then, the idea of a wireless telephone, the very latest use he found for the Audion, had been a secret dream of his for several years. In spite of being heavily engaged in the technical supervision of all the company's stations and plans, deForest had managed to find a certain amount of time for scientific concentration. Now that he had severed relations with the company he was free at last to carry on his research unmolested. Suddenly the whole incident took on a very different light. There was a new goal ahead, a new problem: the construction of a wireless telephone that would transmit the human voice across space.

Up to this time the Audion had progressed far. Although its oscillating characteristics were not known, deForest had very recently fallen upon an account in one of Nikola Tesla's books describing the operation of an electric arc in the flame of a gas light, and a description of its extreme efficiency and stability as a source of oscillating current. He had taken voluminous notes to the effect that this might, if properly developed, prove of utmost value as the transmitter for the wireless telephone. In fact, he had already begun to build an adaptation of the Tesla apparatus. He had tried a straight Poulsen arc, the arc in hydrogen and a number of adaptations made to keep the arc steady and in oscillation. This last method proved the best....

He took off his coat and began to work.

PART FIVE

THE AXIS OF RADIO

I

FOR purposes of simplifying the involved science of deForest's inventions, the story of the Audion, the little tube that made radio history, has been transplanted from its rightful beginnings in the preceding chapters. This division comes about naturally, for from 1906 on wireless telegraphy became deForest's background. Meantime, that tiny spot upon the horizon, the idea for a new detector for Hertzian waves, which had come into his mind back in his hall bedroom in 1900, had been traveling towards him across the years from 1900 to 1906. In the year 1906 he but dimly perceived he was destined to carry on into a new and more spacious realm, a land equally rugged but of much greater area, where a pioneer might at last come into his own.

Not only in the chronology of the life and works of Lee deForest but also in the history of communication, that outstanding chapter in the progress of civilization, the division line between "wireless" and "radio," which is actually no more than a definition of terms, became apparent from 1910 on.

"Wireless" and "radio," as we all know, are one and the same. Every radio station, as Waldemar Kaempffert has so clearly pointed out in his "Popular History

of American Invention," "radiates" its messages, whether they be telegraph signals or spoken words, into space. It requires only the proper electromagnetic ear to hear them.

Nevertheless there is a gigantic speeding-up of processes between the method involved in sending the dots and dashes of the Morse code and that of sending the human voice. To understand this fact one has only to consider the various steps necessary to the sending and receiving of an ordinary telegram by contrast to the idea of two people holding a conversation while one is in London and the other in New York. After 1906 wireless telegraphy became an accepted means of communication and a new wonder appeared, radio broadcasting: instead of the dots and dashes of the Morse code, the sound of the human voice coming across space. It was indeed an invention that "will cause space to shrivel up, that will convert a whole country, even half the planet, into a single huge auditorium." It was christened "radio," symbol of speed and activity.

Considered as a scientific ideal, wireless telegraphy is only a step in the metamorphosis of radio. This idea is expressed with great clarity and vision by Kaempffert when he writes "the telegraph and the telephone have been called space annihilators in their day. Space annihilators indeed! We never really knew what the term meant until the time came when thousands listened at the same time to the voice broadcast through the ether just as if they were all in the same room. Somehow the world seems to contract into a little ball on which Patagonians, Eskimos, Chinese, Americans, Kaffirs, and Apaches are next-door neighbors."

What has deForest's tiny tube, the audion, to do with this conquest of space? Before we consider step by step the drama of the audion as it emerged from an idea in the mind of a raw inexperienced youth working alone in a city room to its present position of undisputed supremacy in radio communication, it is only fair to explain something of the power of deForest's idea in the light of history. Under the title "DeForest's Remarkable Discovery," Waldemar Kaempffert has rendered this task simple by giving perhaps the most accurate and concise summary of deForest's contribution to communication that has ever been written.

"Remarkable as was Fleming's invention of the oscillating valve, still more remarkable was the improvement made by Lee deForest, an American radio engineer. About 1906 deForest inserted a tiny metal grid between the glowing filament of the lamp, or tube, and the metal plate. When the grid was negatively electrified, current would not stream over from the filament through the meshes and on to the plate; but when the grid was positively electrified, the current rushed through the meshes and the plate was charged. The introduction of a grid between the filament and the metal plate does not seem much of an improvement; yet deForest's invention is as great as that of radio communication itself. DeForest had only to include his little grid in the receiving circuit. As it was now positively and now negatively electrified, it assisted or arrested the stream that tried to flow from the filament. He had only to connect his metal plate with a telephone receiver to hear the signals with wonderful clearness. The little grid acted much like the throttle of a locomotive: it set powerful local currents in action,

just as a locomotive throttle has only to be moved one way or the other to start or stop a freight train. What is more, these currents in the receiving circuit were simply a magnification of those that ran up and down the antenna. DeForest could add another lamp or tube to the first and obtain still louder effects. Thus, by adding tube to tube he could magnify a signal millions of times. It is easy to see what this meant in radio communication. Signals too feeble even for detection by Fleming's valve could be clearly heard by a deForest tube or two; the receiving range was increased several hundred times. All the great feats of long-distance radio communication, feats that involve telegraphing half way around the world, have been performed with this marvelous device, 'the master weapon of the radio engineer,' as it has been called.

"DeForest's invention was at once applied in long-distance wire telephoning. Here was a device which made it possible to amplify feeble voice-currents just when they were beginning to vanish altogether. By inserting deForest's tubes at intervals in the line it became possible to telephone from New York to San Francisco. It was thus that the electric current that carried President Harding's oration on the occasion of the interment of our Unknown Soldier in Arlington, Virginia, was multiplied 3,000,000,000,000,000,000,000,000,000 times. Amplified 10,000,000,000 times, the President's words were heard by thousands in Madison Square Garden, New York. Higher amplification was necessary in order that they might be heard in other cities. A deForest tube can magnify the ticking of a watch until it sounds like a trip-hammer. Moreover the tube makes it possible to transmit over a single tele-

phone wire half a dozen different conversations without interference, each conversation being transmitted in waves of a definite frequency."

And in the more strictly scientific sense:

"Although dynamos and arcs are used both in radio telegraphy and radio telephony, the vacuum-tube of Lee deForest has already taken their place; for the tube can be used not only to receive and amplify the feeble waves that come from some far-distant station, but also to generate continuous waves. The time is rapidly approaching when dynamos, arcs, and sparks will all give place to tubes. Only continuous waves will be used, even for telegraphing over short distances. The same transmitting station will, therefore, serve both for telegraphing and telephoning, just as receiving instruments now reproduce both the dots and dashes of the Morse code and the human voice.

"As soon as a method of generating continuous waves, waves that would not die away, was discovered, it became easier to transmit speech through the ether. . . . As early as 1903 Reginald Fessenden had succeeded in telephoning a distance of about a mile. In 1906 he increased this distance to ten miles. From that year on, as the action of deForest's vacuum-tube was better understood, progress was rapid. In 1915 a record was made. The human voice was transmitted from Arlington, near Washington, D. C., to Honolulu. And now we have radio broadcasting stations by which music, lectures, news, and stock-market reports are sent out for hundreds of thousands to hear."

II

But in what state was this remarkable invention, the vacuum-tube of Lee deForest, back in 1906 when the inventor found himself free for the first time to give it his undivided attention?

To fully comprehend the drama, almost the melodrama, of the Audion, we must travel back across the years to 1900 when an eager young experimenter, working all alone in a room in Chicago, found electricity playing a strange prank on him. The idea that resulted, although it proved to be false, developed through the years 1900 to 1906 into an invention whose patents were pending at the very time deForest resigned from his wireless telegraphy company and returned again, just as alone as he was back in 1900, to his laboratory in the Parker Building. The papers he had in his pocket at that time gave him full rights to these pending patents, so worthless were they considered in the minds of his contemporaries. Nevertheless, in the quarter of a century that has elapsed from the night in 1906 until the time of writing, gigantic industries have been erected upon this little device; the executives of great power companies have fought tooth and nail to control exclusively one or another of the

multiple powers it possesses; and the hundreds of millions of dollars it has earned for mankind to date are only the beginnings of its worth.

Back in Chicago deForest had not the time to stop and experiment with the idea which the flickering gas mantle evoked — but he felt instinctively that he had found something.

It was not until 1903 that he found time to draw back upon his past and recall the certain conviction which had never dislodged itself from his mind. Then he began to search for the genuine response to electrical vibrations in the gas flame. He found the conductivity of the incandescent mantle surprisingly small for any voltage which would be practical in a wireless detector.

Experiments followed with the Bunsen burner and other forms of flame. The problem was how to render these flames sufficiently conductive. Salts of alkaline metals were introduced, either injected into the flames as solutions or put into a platinum cup and held in the illuminating part of the flame. This flame receiver, or hot gas detector, 1903, was actually the earliest form of the Audion. It must be borne in mind that it was not in the least a practical device. It must also be remembered that deForest thought of it *only in connection with wireless telegraphy.*

During the period now under consideration, 1903-05, deForest was familiar with the "Edison effect," as indeed was many another experimenter. Even at that time there was hardly a well-equipped electrical engineer who was unaware of that classic result of the experiments made in 1883 by Thomas Alva Edison. All that Edison had done was merely to seal within one of his

incandescent-lamp bulbs a little plate of metal. No contact existed between the metal and the filament of the lamp and yet, when the filament glowed, a current would stream over from it to the plate, but only when the plate was positively charged. This was the "Edison effect." The discovery lay dormant twenty-one years unapplied, until one day it flashed upon the inventor Fleming that this device of Edison's constituted the valve or rectifier that he wanted.

It must, however, be recognized that the Fleming valve was only a rectifier of Hertzian waves. It was not in any sense a *relay,* as was the Audion of deForest, whose basic idea from the start was to devise a "trigger device," wherein the local energy of a battery should be controlled by the incoming electric waves. The audion detector therefore was many times more sensitive than could possibly be the "valve" of Fleming; for deForest utilized the energy of a local battery in circuit with the plate electrode, something which Fleming never did.

During these early years, 1903-05, deForest was afforded little time to concentrate upon the many laboratory problems surrounding this new flame detector. The little time he could spare, however, produced ultimate results of universal application. From the beginning back in 1900, he had been obsessed with the idea of finding a relay detector in which local electrical energy should be controlled by the incoming waves; or as he has himself expressed it, "not a mere manifestation of the electric energy of the wave itself." Hence it was that the "B" battery as a source of local energy was always employed with the incandescent filament and was utilized as the source of electric carriers through the gas.

The battery for lighting the filament deForest styled the *"A" Battery;* and as distinguished from this, the other battery was named the *"B" Battery.* This is a most important item in the genesis of the Audion. The nomenclature of the "B" Battery, so fundamental in its use, has been retained and is today commonly accepted even by the many who for various reasons refuse to recognize the name "Audion." DeForest immediately filed patent application in connection with the "B" Battery, in 1904, for he recognized at once that it was a fundamental device, highly essential to the growth of the idea. Although a more thorough examination of its use will follow in later chapters, in order the more clearly to distinguish between the work of Fleming and that of deForest, it must herein be stated that *the use of the "B" Battery connected with the plate electrode of the Audion basically and fundamentally distinguishes the Audion from the Fleming valve.*

In a paper on the Audion, presented before the Franklin Institute in 1920, deForest said: "At the period now under consideration, 1903-05, I was familiar with the Edison effect, and with many of the investigations thereof carried on by scientists, Prof. Fleming among others. In 1904 I had outlined a plan of using a gas heat by an incandescent carbon filament in a partially exhausted gas vessel as a wireless detector, in place of the open flame. But here the rectification effected between hot filament and a cold electrode was not considered. Two filaments heated from separate batteries would give the desired detector effect equally well. What I had already found in the flame detector and now sought in a more stable and practical form was a constant passage of electric carriers in a medium

of extraordinary sensitiveness or tenuity, which carriers could be in any conceivable manner affected to a marked degree by exceedingly weak electrical impulses delivered to the medium indirectly or through the hot electrodes.

"The ordinary small incandescent lamp of that epoch supplied admirably the conditions I required merely by the introduction of a second electrode. That added electrode could be either hot or cold. Obviously, therefore, use it cold, avoiding thus the unnecessary battery. Then obviously, too, I must connect my telephone or 'B' battery so as to make this cold electrode positive, for otherwise no local current could flow through the gaseous space in the lamp between the unlike electrodes.

"Developments of the engineering staff of the Western Electric Company of the Audion Amplifier as a telephone repeater since my first demonstration to them in 1912 of its possibilities in that field are beyond all praise. Zeal and rare understanding of the elements and the problems of which this staff of trained men developed the amplifier and applied it to the long sought transcontinental telephone line stand unique in the annals of electrical achievement.

"The time was ripe. Had the Audion Amplifier been presented at a much earlier date, it is unlikely that it would have met then the warm welcome the twenty years' futile search the telephone repeater had earned for it. It was the irony of inventive fate, that this revolutionary device was to come, not from those whose efforts had for years spun in the old rut of the receiver-microphone, stuck together like the Siamese Twins, but from an art that was younger, from a device conceived for a wireless telephone detector.

"From small beginnings the transcontinental line has been evolved. One basic invention after another. First the telephone receiver of Bell; then the Berliner-Edison Microphone; then adequate line construction; next the Pupin Coil to prevent voice distortion; then finally the one missing link — the Audion Amplifier. Try to imagine one of the electronic carriers of the voice currents in this amplifier, and contrast it with the microphone transmitter of the early telephone relays. Compare soap bubbles with a load of coal, and you will have some relative idea of the distinction between the delicacy and elegance of the Audion and that of the old microphonic relay. A more revolutionary step was never taken in the history of electrical engineering."

The most important single instrument in modern wireless practice is the three-electrode thermionic vacuum valve, for it enters into every main diversion of the subject — it plays a dominant part in the generation of oscillations, the deductions of signals and in the amplification of feeble voltage and currents. Its arrival and developments have besides helped greatly towards the success of apparatus and methods that might otherwise have remained almost failures. During the war, hints reached the civilian that a revolution was taking place in wireless telegraphy, the principal agency in which was reported to be an instrument called a "valve," a "lamp," or a "tube." This instrument seemed to have arisen suddenly into a predominant position among all the apparatus of the wireless experimenter and operator, and appeared to be of use in every corner of his outfit. The complete name of the instrument is the 3-Electrode Thermionic Vacuum Tube.

It must be emphasized that it is the three-electrode

valve, and not the valve with two electrodes, that has been responsible for the overthrowing of the old methods and apparatus; that it has been a veritable revolution. This can be clearly seen by comparing the common practice in wireless telegraphy of 1914 with that of 1919. In 1914 practically all the most powerful transmitting stations in the world generated waves by spark or arc. These were received at nearly all stations by means of electrolytic or crystal detectors. The spark or arc method of generating waves involved the use of the very large antennæ for spanning great distances; and at the receiving stations, more than 100 miles away, very large aerial structures were required. But today we find most of the high power stations for long distance transmission are "continuous wave" stations; that is, they produce uniform, uninterrupted waves instead of the series of short trains of waves generated by sparks. While at the receiving end new modes of detecting continuous waves appropriate to and taking advantage of their uniformity in character have been introduced. This is where the three-electrode tube in various adaptations enters. Taken together the improvements at both ends of the span have made possible the use of smaller antennæ at transmitting stations, and have almost removed the necessity for any antennæ at all receiving stations.

Years ago what physicist looking at the simple, noiseless incandescent lamp and considering it as an ideal source of electro-magnetic waves of a wide spectrum — of heat, visible, and ultra-violet radiation — wondered why it should not be made to generate also waves of any length? Yet, today, thanks to deForest, that incandescent lamp, with the addition of a metal plate and

wire grid, has become such a generator. Undamped Hertzian radiations of a few centimeters wave-length can be generated by Audions specially designed to give minimum capacity between the three-electrodes and their lead-in wires. From these short waves, representing alternating current frequencies of some hundreds of millions down to those of one or two per second, the electrical wave spectrum afforded by the oscillating Audion is continuous. Consider this fact in connection with the almost infinite sensitivity of the device as a detector, and its unlimited power as a magnifier or amplifier, and one realizes something of the value of the three-electrode Vacuum Tube to the physicist and the inventor. To the former, however, the keenest interest lies perhaps in the Audion itself because there is no known piece of electrical apparatus linking us directly with the most recent work on the structure of matter. A prominent British physicist has recently remarked, "It is probable that there is no other sphere where research work has had such a combination of immediate practical value and intense theoretical interest."

But more than this: "Dr. deForest has recently forecast that signalling by conduction currents of relatively low frequency will soon be practiced through the earth as well as water; and we will find the antennæ of the future thrust upside down as into abandoned oil-well borings and making a contact with deep semi-conducting strata at points separated by a few miles; the two inverted antennæ of such a transmitter, connected by an overhead power transmission line containing the alternating current generator and signalling device; and a similar arrangement for receiving. Then our wireless message will go through the earth's crust or

possibly by a more direct path and not around the earth's surface, not to be tangled up as at present with a bewildering snarl of static ravellings. The Audion Amplifier stands ready to lead us back to the simpler methods of Morse and Lindsay, meritorious methods long ago abandoned because of the lack of an electric ear of indefinitely great sensitiveness.

"The future of radio signalling at sea lies with the telephone rather than with the telegraph. The simplicity and the reliability with which the medium of an undamped wave carrier, ideally suited for voice transmission, can now be had, will rapidly limit the crudity and laboriousness of the Morse code signalling between ships. Yet today, scarcely the dawn of this new epoch has been seen. Vessel owners are almost as skeptical regarding the practicability and utility of the radiophone as we pioneers found them towards the wireless telegraph twenty-five years ago!

"In the future, during fogs at sea, a short wave radio telephone will be used to prevent collisions, distances being determined (as well as direction) by conversation, whistling, signals, or bells, and a calibrated watch. This service will be quite independent of the long range wireless signalling. The new radio has also a wide field of usefulness in telephoning between islands, thousands of which will never be linked by cable. Other useful fields await in sparsely peopled countries, between mines, oil wells, forest patrols, express trains, etc. The future of aviation will be found linked with radio telephone, for a score of different purposes. Telephoning by Audion transmitter, receiver and amplifier, not only carries the complexes of human speech without distortion, but tells the listener when

human speech itself is impossible — amid the deafening motor and propeller noise of the airplane, from one to five miles above the earth.

"Little imagination is required to depict new developments in radio telephone communications, all of which have lain fallow heretofore awaiting a simple lamp by which one can speak instead of read."

But to return now to the early history of the Audion. During the year of 1905 the little device assumed new dignity. It was in the Autumn of that year, while working in his laboratory in the garret of 42 Broadway, next door to the already famous deForest wireless station at that address, deForest's assistant, Clifford Babcock, suggested the name "audion" for this new device. The two engineers both liked the word "audion." It had a pleasant, swinging sound. Almost without thought they adopted and used it whenever referring to deForest's latest achievement.

And Clifford Babcock was also responsible for actually housing the device in glass tubes. In 1904 he had vainly sought to construct some himself, but lacked the necessary equipment to achieve success. In 1905 he went to a New York firm by the name of McCandless, famous for the manufacture of miniature electric tree lamps, and aroused the interest of the sales department sufficiently to have them issue an order for some experimental lamps. These little lamps proved just right for deForest's purpose. In them were enclosed the filament and the plate electrode, the beginning of the radio vacuum tube.

This was the state of the Audion in 1906 when deForest was at last free to give it his undivided atten-

tion. It was in that year that the inventor came across one of those rare ideas which, perhaps once in a generation, or a century, transform or determine the course of civilization. He conceived the notion of adding a third element to the detector, a tiny electrode which he placed between the filament and the plate for the purpose of controlling the electric current between these two. This third element was in the shape of a tiny grid-iron, from which it derived its popular name, the grid. The significance of this third element, as it appeared in its raw form fresh from the inventor's mind in 1906, has induced no more interesting comment than that written by deForest himself.

"In the beginning of the first century, Seneca was attracted to the beauty of the written word as it appeared through the magnifying power of a glass tube filled with water. Writing had suddenly become beautitful. The water in the tube made small and indistinct letters large and distinct. This simple effect led observers to try the effects on smaller tubes and thus obtain magnifying powers sufficient to discover invisible phenomena about us in the world everywhere.

"Think of looking at a written word through a glass of water. It is a far call from the microscope of today, that miraculous invention that shows us the presence of objects too minute for the human eye to observe, unless they are rendered thousands of times their size. It opened the way to a realm of physics of which man had never before dreamed. Yet the glass tube filled with water is no further removed from the present microscope than was my first crude gas detector from the Audion of today which is as perfect and sensitive as a magnifier of sound as is the microscope as a magnifier of sight."

III

As he stood working in his laboratory in the Parker Building upon that memorable night in the Summer of 1906, deForest was too preoccupied with the experimenting involved in the difficult task of transmitting the voice across space to take stock of himself as an individual. He did not realize, for instance, that he was already thirty-three years old, and that he was literally starting out anew. He did not stop to think that the kind of courage which forces a man on after he has seen his fortunes swept away, his years of struggle and achievement destroyed by lesser men, is a characteristic possessed by only a few of the great men of all time. It did not even occur to him to wonder how, on the very night of that day on which he had seen the bitter end to all his hopes, he was able to achieve such complete concentration.

When at last he left his laboratory late that night, the group of circumstances that had appeared so tragic and hopeless earlier in the evening faded into perspective as a whole new flood of ideas on transmitting the voice rushed into his mind. Wireless telephony! Here was a fascinating new realm for experiment and invention. Here was the broadest scope of science he had ever

contemplated. The successful transmission of the human voice across space would annihilate distance much more completely and effectively than the transmission of telegraph signals. His thoughts led one into another as he considered the hugeness of this new idea, a project peculiarly suited to his present needs. Somewhere in his speculations appeared the word "pioneer," the one word that epitomized the inventor's ideal. Here was a land for a pioneer, new and untried as a jungle. He had already tested out wireless telegraphy and set it upon the American map. That was a conquered field. What he had hoped to acquire from his achievements for his company was in the form of a well-equipped laboratory with able assistants and hours of leisure in which to experiment. In other words in one way or another he was turning from what he had accomplished towards what was still an idea, still a laboratory child, that had to be nursed along.

The fact that he had not acquired the laboratory of his dreams seemed suddenly not to matter. After all a pioneer must work in the dark; he must struggle with the elements; and the fun is in the fighting. When he has conquered one land he does not wait to hear his praises sung. He is already plunging forth into another.

There was a goal just ahead: the transmission of speech across his laboratory and across the universe. At least he had a place in which to live, a laboratory in which to work, and he knew that his young assistant, John Hogan, would not desert him because he had only five hundred dollars in the world. He would begin tomorrow morning to ally himself with wireless telephony just as in the beginning of his career he had allied himself with wireless telegraphy. It would not be

easy. Struggle, deprivation, and hardship would begin anew, and since he had lived in comfort the return to poverty would hurt now more than the early privations. But there was a goal ahead, the thought of which thrilled him. He looked forward to returning in the morning to his laboratory in the Parker Building, forgetting indeed that it was a meagre and ill-equipped room instead of the modern palace of experiment of which he had dreamed so long and well.

We have seen the state of the Audion in 1906, immediately after the collapse of deForest's interests in his wireless telegraph company. Up to this time, in spite of its scientific progress, the Audion was by no means a practical device. The two outstanding facts concerning this new form of detector as it appeared then are first, that it was still in its laboratory stage, the second state in the metamorphosis of any invention; and second, that it was thought of, up to that time, only in connection with wireless telegraphy.

The remainder of the year 1906 and the whole of 1907 was devoted entirely to the wireless telephone. With deForest able at last to concentrate upon the many laboratory problems involved in the development of the Audion, this invention literally swept on to its final development with increasing brilliance in each new stage. With only his young assistant, whose heavy bass voice possessed the frequencies most useful in telephone testing, to help him in his intense experimental work, he achieved amazing results. It was in 1906 that he inserted the tiny grid between the filament and the plate, and in this form patented his three-electrode tube. On the

very last day of the year, December 31, 1906, the first speech was transmitted across his laboratory. He immediately took steps to patent the Audion as a telephone repeater or a relay, in addition to its use as a detector in wireless telegraphy for which he had first invented it. These two patents, the three-electrode tube, and the use of the Audion as a telephone repeater, have since been recognized as two of the most important patents ever taken out in the United States Patent Office. They represent inventions that have completely revolutionized mankind's methods of communication, even his habits of life, and upon them have been built industries which, in the short space of twenty-five years, represent more than a billion dollars of wealth.

The beginning of the new year, 1907, was the beginning of a new life for deForest. Although New Year's Day found him with funds too low to celebrate that festive occasion as was his wont, he had definite proof that he was correct in believing wireless telephony entirely possible. And this was joy enough. Back in his laboratory was the nucleus of a commercial wireless telephone! It no longer needed to be nursed along. It had spoken for itself on the last day of the old year. The New Year saw it an accomplished fact. What if his laboratory apparatus was bulky and heavy and not adaptable to commercial installation? The problem that lay before him now was comparatively easy. He would have to make the apparatus practical. He would have to work and experiment until he had achieved a device that was at once simple and rugged, and of sufficient strength and dependability for commercial installation. But if the six months that had elapsed since deForest's first alliance with wireless

telephony had seen the invention through its laboratory stage, what would not the year 1907 bring in? Besides, in the problem of creating radio apparatus deForest's long years of experience with wireless telegraphy would stand him in good stead. He had not watched for nothing his own early wireless detector, the impossible "Sponder," emerge from a bulky and unadaptable apparatus to the thoroughly dependable commercial sets of the day.

The quest took on new tempo. He would apply himself with redoubled effort. The wireless telephone would have to be made available to the public. There would have to be commercial installations; a wireless telephone company backed by men of vision, financiers and industrialists who could "see" the place of the wireless telephone in world communication; an entirely new organization ruled by an imagination that was inventive rather than scheming, and that would brook no defeat.

IV

THE company that was formed in the Spring of 1907, the deForest Radio Telephone Company, was large in achievement if limited in funds. It developed the three-electrode or grid audion as a detector both for wireless telegraph and telephone reception. It controlled all of deForest's radio telephone patents, as well as some several odd patents pending for the audion and various applications thereof, and had listed to its credit the intense development of the Audion after deForest's vitally important discovery that this device could also be used as a telephone repeater or amplifier.

Its organization, however, made little difference in deForest's work. The company began its operations in the Parker Building, a building that towers high in the history of communication, for in it the three-electrode audion was first tried out and found successful as a detector of voice signals. But the company had insufficient funds with which to develop deForest's wireless telephone system; hence its subsidiary, the Radio Telephone Company, was formed late that same year, and acquired all the deForest patents. At that time deForest was fortunate enough to secure from his friend, John Stone, wireless inventor and scientist, all the latter's

numerous and important patents on tuned wireless circuits which, of course, went along with deForest's own patents to the organization controlling the Radio Telephone Company.

Meantime deForest himself was busy perfecting his apparatus, trying out first one design and then another in order to find the best means of presenting the "radio" telephone to the public. The final form first used for public demonstration was in the form of two cases with sliding panels on top. The apparatus was contained within the cases.

The very first installation of the radio telephone on record was just as unpretentious as had been the early wireless detector. One fine day in the Spring of 1907, deForest and two assistants boarded a Lackawanna ferry-boat on the Hudson and began work on the installation of the first moving wireless telephone station. The skipper of the ferry, the *Bergen,* who had no interest whatsoever in a wireless telephone, and no knowledge of the fact that the interest of the Lackawanna Railroad officials had been aroused to the extent of erecting a land station at the Hoboken terminal of the ferry and another at 23rd Street, Manhattan, viewed these strange operations with deep contempt. The bags of apparatus looked to him like plumbers' kits; the men like mere intruders upon his own domain.

What had begun as an experiment ended as a public demonstration. Communication between land stations and the *Bergen* was easily made. The newspapers carried full columns describing the latest advance of science, the radio telephone of Lee deForest. An item appearing under a photograph of deForest, tells the story of activity and achievement: "Lee deForest, famed for

his inventions in telephony without wires, has installed a telephone service between Jersey City and New York which needs no wires to operate. Practical tests of his apparatus have been made and the Lackawanna Railroad has become so convinced of its practicability that a regular wireless telephone line is to be operated between their docks across the Hudson River and New York. As an illustration of what Dr. deForest has accomplished with his latest invention, it may be said that the human voice and the sounds of a gramophone have already been transmitted by his instruments for a distance of 12 miles — from a point on shore to a steamship in lower New York Bay. As soon as its efficiency has been still further tested, it is promised that the North River ferry-boats will be equipped with the apparatus. . . ."

And all this within the short space of a single year!

The age-old problem of how to get money to carry on, reared its head higher than ever, casting its shadow o'er the inventor and his affairs, and blocking the way to success. As usual the unpleasant task of thinking up ways and means of raising the needed funds rested upon deForest, who was so ill-equipped with financial ability and whose interests were now more than ever in his work. At the age of thirty-four it was harder to leave his laboratory and go down into Wall Street than it had been in his late twenties.

But if the problem of raising money was old in deForest's life, the spirit of faith and optimism was still older, and stronger. It was not long before an idea came to him, an idea that automatically wiped out his

horror of interviewing brokers and bankers in Wall Street. He would go and see his old Yale class-mates and ask them to buy stock in the wireless telephone. Some of his old friends at college were now wealthy men who would doubtless be grateful to anyone who provided a means of making a large return upon money invested. He would make this project a class affair of Yale '96 S!

The idea was good in that its momentum carried him forward into Wall Street where sooner or later he would have had to go anyway. But the brokers and bankers who had been interested in anything that would help change and better the world while at college seemed suddenly to have been set in a dull conservative mould. They could not "see" the wireless telephone. DeForest found that he would have to explain from the ground up. And so he would begin.

"Ether waves are used in the transmission of wireless telephony, just as in wireless telegraphy. The present form of wireless telegraphy is that of vibrations arising from a noisy flashing spark, and these act upon a detector which makes the sounds of dots and dashes of the Morse alphabet in the telephone receiver.

"In the same way, but with an arc instead of a spark gap, I generate a continuous succession of electric waves which are utilized in transit to carry the sound of the human voice. When you speak into the microphone transmitter on the wireless telephone your voice changes the resistance of the circuit and a larger or smaller part of the high-frequency current goes into the aerial wires which are elevated some fifty feet above the building.

"We use much stronger currents than in the wire

telephone. At present we employ the ordinary Edison current of 220 volts, the same power that is used for electric lighting. The atmospheric disturbances will not affect the wireless telephone nearly as much as they do the telegraph, for one is able to distinguish the human voice through a great amount of disturbances."

If encouraged at all, he would continue:

"The feature about my radio telephone is that it does not need a trained operator. Any person of average intelligence can operate it. To call up a station you first throw on the power by closing a switch. The next move is to set a little disc to the number of the station you want, and adjust a thumbscrew until a pilot lamp burns. Next you set a tuning rod until the needle on the quadrant corresponds with the number on the disc, and your connection is established. It takes longer to describe this than it does to do it.

"All the time one is talking it is necessary to press a small button, releasing it at the end of every sentence. To listen to a message you place a headpiece on your head and receive it as you would with the ordinary telephone."

There followed the inevitable business man's question:

"But what good is it if not commercial as an office to office or house to house proposition?"

And deForest would answer:

"The future of the wireless telephone is without limit. It is true that at present it will not be of much use in large cities, as it will not be possible in these early stages to get more than say ten different instruments attuned to ten different tunes or frequencies.

Eventually we may get a hundred, or even a thousand tunes. Then the picture will be a very different one.

"But even now the wireless telephone can become invaluable to small vessels, mines, lonely ranches, and lighthouses. For the navy, in manœuvres or in battle, it will be of inestimable service. An installation could be fitted in the chart room of all our warships, and commanders could talk directly to each other. There would then be no danger that an order had been misinterpreted in passing through other hands. So highly did Admiral Cowles, Chief of the Bureau of Equipment in Washington, think of it that he told one of my directors he wished we were ready to deliver fifteen at once to the Navy.

"And there is another angle to the wireless telephone. While I was experimenting with the wireless transmission of music last March from the Telharmonic Hall, at Thirty-ninth Street, to the Hotel Normandie, on Thirty-sixth Street, the wireless operator at the Brooklyn Navy Yard, four miles distant, heard on his instrument the overture to 'William Tell,' followed by Gounod's 'Ave Maria.' In the evening he came over to New York, called on the manager of the Telharmonic Hall, and asked him what new arrangement they were trying, as he supposed that what he had heard had come by induction from the telephone wires. It is a question of years, of course, before we can send song and music out upon the wireless telephone, but when we do it will have become an invention of the greatest value."

In other words, as far back as 1907, deForest conceived the idea of broadcasting and foresaw its possibilities.

"The invention is only in its infancy, and we do not

know the limit of the range at which you can talk. I am positive that even now I could talk with Sandy Hook, and if we go on at the same rate of progress, in five years or less we shall be able to project the voice 500 miles, and by the same argument in fifteen years we ought to be able to talk across the Atlantic."

No word need be said for the far-sightedness of DeForest's prophecies. But Wall Street men, even of Yale '96 S, could not see the wireless telephone. Each and every one steadily refused to take any interest in his invention. He tried to appeal to their class pride, but without success. They did, however, consent to lend him small sums of money on his personal note. Out of all his interviews he succeeded in raising five hundred dollars!

Incidentally, had these Wall Street men answered deForest's urgent plea, the class group would have owned and developed the Audion patents and been today one of the richest groups in the world. At class reunions, when congratulations pour in from all sides, and deForest, who is always comradely, always glad to see his old friends, enjoys the buoyant sensation of pride in his own achievements, he nevertheless permits himself the luxury of indulging in this memory.

THE unusual circumstances that seemed always to crowd about deForest, at times crowding him out, came stronger than ever in 1907. The panic of that year that shook the whole country tied up the loose moneys that might, in better times, have been available. Discouraged and embittered by the failure of his college friends to stand behind his invention, deForest hesitated to go out again. Instead he retired into the comforting precincts

of his laboratory in the Parker Building, and found relief from his anxiety in the marvelous progress which he was achieving in the wireless telephone.

Whatever the attitude of the investing public, de-Forest had an enthusiastic audience consisting of two wireless amateurs who were deeply interested in what he was doing. The Parker Building was situated just two blocks away from the Metropolitan Life Insurance Building, where Miller Reese Hutchinson, who has since become famous, was busily engaged in improving the Klaxon horn. Like deForest he was experimenting, and he needed relaxation. Hutchinson's favorite diversion from his experiments was to listen in with his small radio set on the activities of the wizard deForest, who he knew was located in the Parker Building. He did not know that he was not the only member of deForest's audience situated near at hand. Just a block farther away, in one of the rooms high in the Madison Square Tower, was Peter Cooper Hewitt, who was never without his wireless set and who watched deForest's amazing achievements with the greatest interest.

To get a complete picture of this dramatic little group, bound together only by the most impersonal of interests, one would have to travel back to 1907 and conceive again the colossal novelty of the idea of transmitting the voice across space. Hutchinson was so excited by deForest's work that on several occasions he helped by keeping watch at his receiver while deForest carried out tests or conducted experiments at some new piece of apparatus. On these occasions Hutchinson and deForest would hold long conversations over the telephone wire which connected their two offices, arranging an elaborate system of signals for reporting results of

the tests. Groups of people on the street below would be astounded to see a man leaning far out from one of the upper windows of the Metropolitan Building waving a slightly soiled towel up and down in the air. Was the man demented? Was there a fire inside the building? These same people, who found it difficult to accept the event of anything unusual without the epithet "crazy," would doubtless today find it difficult to believe that those signals had more to do with the operation of the present radiophone than any other act in the history of the art; for it was as a result of these tests that deForest continued his work, finally bringing his wireless telephone to such a state of development that commercial success was inevitable.

Adventure followed adventure. One morning deForest went to answer the phone hanging on the wall at the very end of the laboratory, failing as he went, to turn out the arc or stop the phonograph which was grinding a record on to the air. The voice at the other end of the wire informed him that Peter Cooper Hewitt was speaking from the Madison Square Tower. He said, "Listen." DeForest listened. Music, strangely familiar music, drifted in to him through the telephone receiver. Instinctively he turned toward the phonograph connected with the arc transmitter. Just then the music in the telephone stopped short and a gr-r-r-r-r followed it. Baffled, he watched the arm of the phonograph swing into the center of the disc. It dawned upon him that the music being broadcast had been picked up by Hewitt and sent back to him over the local telephone line!

Among the many and varied stories of "wireless" and "radio" to be found in the yellowed newspapers of

the Spring and Summer of 1907 is one strange tale of three brothers who, in the basement of a building just across from the Metropolitan Opera House, were creating "synthetic" music. Although the music was created by purely mechanical means the tone was more perfect than that of a genuine Stradivarius. These three Cahill brothers had weird and marvelous tricks. By shifting a few switches their apparatus would perfectly reproduce the low rumbling notes of a kettledrum in F sharp. Musicians from all over the city came to look and wonder. How a bunch of wires and a series of whirring dynamos and a contraption of iron and steel could be made to produce the beautiful music of seasoned old instruments was indeed mysterious.

The three brothers who had invented and were now engaged in perfecting the machine had a motive more important than that of merely amusing the public. They were looking for a commercial outlet for their remarkable synthetic music. The word had not yet come into use, but what the Cahill brothers were actually looking for was a means of "broadcasting" their excellent if machine-made music. They called their machine the "Telharmonium," and their first thought was, naturally, the telephone wires. Followed long conferences with the officers of the New York Telephone Company in which the Cahill brothers made offers for the use of their established lines. But the executives of the telephone company considered the idea in the light of a novelty which would bring them small gain were they to allow their lines to be used. Their engineers presented the scientific aspect of the picture. If this music were allowed to pass over their lines, accustomed to only a fraction of an ampere of twenty-four volts, disaster

would inevitably follow. It was easy for the executives to picture the induced current from this heavy charge spreading all over the lines, burning out ringing coils and disrupting the work of years. The Cahill brothers were refused the use of the telephone wires.

The next move was to go to Albany to see if the State Legislature would grant them a franchise for running cables under the street. All might have gone well and the Legislature been prevailed upon but the inevitable officials of the telephone company were again present. They pointed out to the Legislature that their company's franchise was exclusive and that no other cables could be run under the streets near theirs.

While this was happening, deForest had heard of the Telharmonium and immediately had seen the adaptability of this synthetic music to his own wireless telephone. Having taken the trouble to acquaint himself with the Cahill brothers' moves in New York and at Albany, his course of action was clear. He went over to see the Cahill brothers and to examine their machinery. Even casual scrutiny of the Telharmonium revealed to him the advantages of broadcasting this music, for the powerful current generated did away with the necessity of the microphone. (Heretofore modulation was accomplished with the microphone in the antenna or ground circuit of the transmitter, thus creating the necessity of using a microphone designed to carry extremely large currents. The types available were continually jamming and choking and limiting the output of the wireless telephone by their own incapacity.)

With the microphone out of the way, deForest saw at once the advantage of combining the wireless tele-

phone with this new form of music and held conferences with the Cahill men and their backers, resulting in the usual request for a demonstration. He agreed; brought up one of his transmitters for installation; connected it up; erected an antenna on top of the building; and placed a companion receiver in the Times Building at Times Square where the Cahill brothers were listening in. Perfect and clear music came in. DeForest began to talk business. He pointed out to the inventors that wireless was the only solution to their problem; that even the cost of installation was smaller than for the wire system.

The people to whom he was talking were without imagination. Wireless was new. They did not want to try anything new. After one of the large and established corporations had made use of wireless, of course, that would be another story. Then they would come to the officials of the corporation to talk business. "And be refused the use of the ether," deForest finished for them.

He left thoroughly discouraged by the incident, with only one happy thought in mind. The transmission of the Telharmonium music over four blocks through steel and traffic to the tower of the Times Building was the first development of his idea of sending and receiving music. He did not know that this little incident was the first actual broadcasting as we know it today, harbinger of a gigantic industry of world-wide scope.

It is easy to trace the effect of these early experiments upon the imagination of the inventor. As far back as 1907 he was beginning to organize his knowledge. He

had actually conceived of the idea of radio broadcasting, envisioned music, words and song being sent and received over the entire world. What Lee deForest was accomplishing in his little laboratory in the Parker Building back in 1907, with only the strange audience of interested neighbors, accords marvelously with Havelock Ellis's definition of science. Science is not indeed the "accumulation of knowledge in the sense of piling up isolated facts, but the active organization of knowledge, the application to the world of the cutting edge of a marvelously delicate instrument, and this task is impossible without the widest range of vision and the most restless fertility of imagination."

In deForest's own words, written in answer to a request from the editor of "Success Magazine" as to what was and has been his ruling ambition throughout his life, we have his "world-picture" back in those dark and difficult days when the very idea of Internationalism was as remote in some dim and far-away future as the Inquisition in an equally remote past.

"My ruling ambition, while I was entirely occupied with my work in radio, was to see the Radio Telephone, through the universal channels of broadcasting, become a medium for bringing into each home the very best in entertainment, education, information, which the leaders of all these fields have to offer. To see radio become an immeasurably potent medium for rapidly widening the mental horizons of millions of people more isolated, less accessible to the better things in music, lectures, and general culture than are the fortunate few who can have those things direct. To shed from countless firesides a new light over lives heretofore dull and colorless, to brighten the long hours of isolation, to make life in

rural districts more than mere existence, to awaken to new interests minds and souls that but for it must still slumber in sloth or decay in discontent!

"I saw in the radio telephone the ingredients of a new world cement, as penetrating and binding as it was invisible and intangible, to bind together the various peoples of the continent and finally of the globe in a quickened intelligence, a livelier sympathy, a deeper understanding. This, in time, would spread the knowledge which alone will end war, immeasurably hastening the day of a universal language, a world-wide acquaintanceship."

V

These adventures, seemingly so small, but actually epoch-making, of deForest and his neighbors, could only support his optimism for a certain length of time. Even the mighty ideal of world-wide radio that was before him day and night faded and grew dim before the all-pervading facts. The panic of 1907 was on. He had recently found himself one of a long list of men waiting before the paying teller's window in a downtown savings bank, warned by the newspapers to withdraw their money before the bank went into the hands of the receivers. After his classic failure to raise money from his college mates, deForest was too discouraged to venture further into the world of finance where unbelieving and unimaginative men put to naught the work of years.

When things looked their very blackest there came an invitation to demonstrate this new wonder, the wireless telephone, at Put-In Bay, Lake Erie, by installing one upon Commodore Huntington's private yacht, the *Thelma,* a seaworthy little craft of some forty feet, whose owner was anxious to take some part in the forthcoming yacht races to be held on the Bay. DeForest saw his opportunity; summoned his true and tried

wireless operator, Frank Butler; shipped from New York the necessary parts for the apparatus, and hurried to Lake Erie. The apparatus was installed in the cabin, the generator which furnished the power for the arc transmitter placed alongside the boat's engine, and a "phone panel" placed adjacent to the wheel.

As the *Thelma* took her few preliminary turns the operator at the phone made his first call to the shore station. To his great delight when he threw the set over into the receiving position the answer came through booming, including the growl of the engine and the shouts of the captain and passengers. This same perfection continued mile after mile as the boat steamed along towards the finish. Every second of the races the two men at the radio telephones were in perfect communication. At the finish line some ten miles from shore the sound of the gun was picked up by the microphone several seconds before the sound itself had travelled the distance. Those who were near the receiving station stopped to comment upon the extraordinary illustration of the speed of travel of radio waves!

Newspaper reporters were lavish in their praise of the radio telephone, one of the most colorful items in the panorama of the races. It was just what deForest needed for it was followed up by a letter from the Navy Department asking whether or not it would be possible to install two wireless telephones on the U. S. S. *Virginia* and *Connecticut,* and give the apparatus a test under actual operative conditions. The stipulations of the trial were that the apparatus was to be simple, steady in operation and cover a range of ten miles.

DeForest immediately put his whole laboratory force

on the job of constructing the two test sets. The men worked with the greatest concentration for they realized that opportunity had thundered at their door. After all the United States Navy had been the first institution in the world to realize the possibilities of the Audion, having purchased the first audion detectors — these were the two-electrode type — in 1906. It would seem to follow that the Navy would again be the first great public institution to purchase the three-electrode type, and this happened. So deForest and his men applied themselves with passion. Roscoe Kent, who had helped install the big transmitting station at Guantanamo, Cuba, and who was then on a leave of absence as chief electrician of the Navy, brought his experience and wide acquaintanceship to deForest's aid.

In due time the sets were installed off Cape Cod on the *Connecticut* and *Virginia.* Perfect communication was established and continued for twenty-one miles, eleven miles more than the required distance! The date of these tests, September, 1097, marks the very first Navy installation of the wireless telephone in the world.

These installations brought great success. The tests proved so interesting and valuable that Admiral Evans, "Fighting Bob Evans," insisted that every one of his famous round-the-world fleet of battleships and torpedo-boat destroyers, twenty-four in all, be equipped with radio telephones. It was a gigantic project. Besides the sixteen battleships there were six torpedo destroyers and two supply ships. Everyone connected with deForest's project realized that the successful fulfillment of this huge contract meant the final endorsement by the U. S. Navy, with its inevitable result: the turning point for the struggling wireless telephone.

Admiral Evans' fleet was shortly to start its famous trip around the world. The time allowed before the sailing was not nearly sufficient for the assemblage of the various sets and their proper installation. So de-Forest began another rush job. The inventor and his aides remained at their work-benches day and night, stopping only to snatch a sandwich or to stretch out on chairs or a packing case for a few hours' sleep. DeForest actually slept so little and ate so irregularly that he wondered himself at his own survival. The interval before the fleet sailed was so short that the small body of workers, John Hogan, Roscoe Kent, Frank Butler and Ford Grieves, all deForest men who have since become shining lights in radio, had hardly finished the apparatus before it was rushed off by express to Hampton Roads where the fleet was being hurriedly outfitted!

The building and testing of the Navy equipment in the laboratory of the Parker Building, seemingly a gigantic job, eating up the nerves and the energies of the workers, brought in one bright adventure, one incident that was wholly gay. It was during a test that de-Forest was making upon a new piece of apparatus. Rather than constantly use his own voice while speaking into the detector, he had employed a phonograph record. The inventor did not know that while he was innocently at work putting part of an old speech and some phonograph music on the air a wireless operator in the Brooklyn Navy Yard was finding cause to question his own sanity. What had happened was that the operator, who had been drinking, could not believe his ears as he found himself hearing strange words and music coming in over his ear phones. He called upon

the chief electrician, George Davis, to don the earphones and listen. He heard and was likewise astounded. The four other operators tested the veracity of this strange business and found it true.

Then George Davis remembered the name of "Doc" deForest, "the only man in town who could be doing such a thing." He went to the telephone and called deForest and questioned that miracle man as to whether or not he was responsible for this latest freak of sending out talk and music to frighten many operators. DeForest replied that he had a wireless telephone working and asked Davis what he thought of it. The latter's imagination had been excited by the thing. He declared that he liked it better than anything he had come across so far. The incident was indeed prophetic, for it illustrated beyond all doubts the possibilities of broadcasting as deForest saw them even at that time.

The men came on to Hampton Roads and work began with deadly concentration. The destroyers were equipped first. The workers left the last of the destroyers just as she was clearing out the docks. There was absolutely no time left for trial tests or instruction of operators. The work began on the battleships. Roscoe Kent sailed down on the flagship *Connecticut* as far as Trinidad, in the West Indies, for the purpose of training the operators, but since he could not get on the other ships until they docked at Trinidad, instruction was limited to but one group on one particular ship. In spite of these terrific handicaps some new records of over sixty miles had been established by the time the fleet reached San Diego, California.

As soon as the fleet sailed, deForest returned to New York more dead than alive. Nevertheless he had the

happy knowledge that Fighting Bob Evans' important fleet of cruisers were each and all equipped with a "deForest radio phone," and each of their commanding officers in communication with all the other officers of the fleet. It was a great milestone in radio development. It remained now but for the men in the money markets of Wall Street to realize the significance of what he had done.

Success with the Navy brought some recognition. It did not bring what deForest had hoped: the permanent interest of Wall Street in the radio telephone. Nevertheless it roused public interest to such an extent that during the darkest period of 1907, twenty thousand dollars were invested in the radio telephone. This enabled deForest to project his idea further into the world; to take care of the men who had come into his employ for the glory of the venture; to make plans for the first radio telephone exhibit which he intended to set up at the Electrical Exposition to be held in Chicago early in 1908.

But the "Captains of Industry" could not see the future of radio telephony. "What is the use?" they inquired of deForest who wrote his answer to *The World* under date of April 7, 1907.

"Now comes the eternal question of the utilitarian, 'What's the use?'— the most pertinent question, by the way, ever asked. What is the use of speaking across hundreds or thousands of miles? What is the use of listening in your own home to the melodies of master musicians played in some distant Auditorium? What is the use when some distant mariner, fog-bound and lost,

unacquainted with his bearings and the Morse code, can call to a listener on the nearest shore and hear in a still, small voice his name repeated and his whereabouts disclosed? Or perhaps he will hear an answering 'Ahoy!' and be told that another craft steering a certain course is close upon him, and by steering oppositely avoid certain collision. What's the use, when a tug's captain can be in easy telephonic communication with his barge office miles away, or with the steersman of his tows, even if the hawser has parted? Or when the admiral, on his bridge, can give his orders direct *viva voce* to all or any of the commanders of his widely scattered squadron?"

VI

Somewhere in deForest's dogged planning to broaden the materiality of his idea, another group of thoughts of a nature entirely new, that could not be answered by the rigid laws of science, was consuming his attention. In a word, Lee deForest was in love. The object of his affections, Nora Stanton Blatch, whom he had met during the bitterest of his early struggles in 1906, was a prominent woman engineer, the first woman to receive a civil engineer's degree from Cornell University where she had been graduated in 1905. In her college days, Miss Blatch had helped in the survey of the New York State watershed. After her graduation as a full-fledged Civil Engineer, she had obtained a position on the New York City Board of Water Supply. So great was her sympathetic interest in deForest's ideas, however, that she gave up her work for the city and went to study under Professor Pupin at Columbia. It was a stiff course in electricity and mathematics that this young woman mastered with amazing intelligence, but it opened up the pathway to the scientific life of the inventor who was soon to be her husband. On February 11 of 1908, that year that was so replete with incident, the New York newspapers carried an announcement

of the engagement of Miss Blatch to Lee deForest. Between the lines of commonplace information, "Mr. and Mrs. deForest will sail for Europe after their wedding and make a tour of the scientific laboratories of France and Germany," lie whole chapters in the life of Lee deForest, the color and excitement to which his nature was well attuned, the ideal of internationalism that was before him now no matter what he did.

Before he was to achieve the voyage that gave him so much, a bitter trial awaited the inventor, one of the bitterest and saddest in all his life. And with the customary super-cruelty of fate, it came just as he was realizing some long-cherished dream. It happened at the Electrical Exposition in Chicago where the deForest radio telephone exhibit was arousing tremendous interest. Public and press alike found cause to gape at the sight of people talking to each other without wires from a booth downstairs to a balcony at the end of the hall. DeForest was present in person every day of the show until a bit of information reached him in the form of a telegram from the President of his company in New York. His laboratory had burned down. The Parker Building had been destroyed, and in its heap of ashes lay the inventor's priceless apparati, notebooks whose contents he could never duplicate, every sample of early audion tubes showing the complete evolution of the device from the early gas detector to the present three-electrode tube. The friend who sent the wire added that the fire had begun in the lower part of the building. So that deForest, had he been in town, would undoubtedly have been hard at work in his laboratory on the top floor, and so would have met his death.

The flavor had gone out of the show, and out of

existence. DeForest returned to New York and set up a temporary laboratory on West 14th Street. The gloom that surrounded him might indeed have been disastrous but for the prospect of his forthcoming honeymoon, and the necessity of constructing new equipment with which he proposed to conduct some spectacular experiments abroad. The feverish activity to re-equip a laboratory and remake the necessary radio telephones he intended to take with him helped at last to assuage his grief over the tragedy of losing his laboratory. And when finally he set sail with his bride for France early in 1908, he completely forgot the horror of his loss in the brilliant prospect of talking by wireless telephone from the Eiffel Tower to every wireless station in France.

This idea, which was obviously the most far-flung the inventor had yet conceived, was considered an impractical dream by those who had heard it in deForest's own words just before he sailed. Nevertheless the first day in Paris saw negotiations completed for use of the Eiffel Tower for his experiments, and the second saw that notable structure changing its aspect as the first radio phone was installed on French soil. From the sides of the Tower antennæ were hung, and in its base the American's generator was installed. No sooner had this work been completed, than tests with the French military stations near Paris were begun. At slightly more than twenty-eight miles beyond the Eiffel Tower, the signals began to fade out. Within a few days a range of twenty-five miles had been established as dependable under all conditions.

When the night for the big test arrived, having

learned that he would be allowed to use the main antenna which ran almost to the top of the Tower for experiments, deForest and his assistants, chief among whom was his wife, stayed at the transmitter all evening, feeding records to the Pathé talking machine which was modulating the carrier current. All night long they stayed at the Tower, returning to their hotel in the early morning to await results. The stations had all received the program. But deForest's success went deeper. A letter postmarked Marseilles written by an engineer who had listened in exactly five hundred miles away, told of the complete reception of the program. Those who had been skeptical of deForest's great "scheme" were confronted with newspaper stories that day that told of how "An American Inventor's System Proves Highly Successful in France." It read: "During the past week in Paris, Dr. Lee deForest conducted several remarkable exhibitions in radio, or wireless telephony, talking from the Eiffel Tower to all wireless stations throughout France. This was all done under the auspices of the French government, and prominent army and navy officials were present, all declaring the tests most satisfactory."

These skeptical persons were doubtless even more surprised to read the rest of the story which told of how "next week Dr. deForest will commence installing the system on the ships of the Italian navy. Further, the Great Lakes Radio Telephone Company will establish over two hundred stations around the Great Lakes, and then it will be possible for any citizen of Michigan to sit in his home and talk to people on the vessels as they ply the waters."

The next scene of action was in Germany where deForest gathered about him the great scientists of that country to interchange ideas, to demonstrate apparatus, and to round out what indeed might be called a conquest of Europe. In Germany he demonstrated his Audion to many great men who were beholding it for the first time, men who watched and marveled, and left still marveling at its power.

The American had another idea, a truly radical invention of great help in surgery, called the "cold cautery." It was a simple process. A very fine platinum wire connected through an insulating handle which the surgeon's hand grasped and connected by a single small flexible wire to a high frequency generator. While at work the preceding year deForest had discovered that a cold metallic body like a needle thus energized possessed the faculty of cutting, or searing its way through flesh, closing up the ends of the blood vessels as it cut or burned through. Thus many tedious and delicate operations could be made without fear of loss of blood or danger. He found the leading European surgeons very much interested in this new invention and its possibilities. He had already taken out several patents in various countries. In spite of this gratifying interest the invention was nevertheless first put on the market in America, but not for many years after these first demonstrations abroad.

Good fortune seemed indeed with the inventor at last as he sailed back to America, with the radio telephone upon firm foundation. The crowning incident that rounded out his European accomplishments came just as he was about to leave for New York. The in-

stallation on the ships of the Italian navy had aroused such great curiosity among the British Admiralty that these gentlemen felt they could no longer afford to ignore the radio telephone. Whereupon they sent de-Forest an invitation to test the wireless telephone on their fleet. The inventor replied that he was about to return to his laboratory where he intended to build still more powerful telephone transmitters, and that he intended to return with these to the continent and would be glad to give a demonstration on any or all of His Majesty's ships. DeForest saw in the opportunity offered by the British Admiralty the possibility of a large order, and a better financial situation for the new Radio Telephone Company, in whose interests he was eager to return to New York.

Mrs. deForest, who had assisted her husband in his achievements on the continent, had become so enamoured of his work that she had decided to take up the study of condenser making in Basle, Switzerland, in order to be able to assist in the electrical laboratory, or perhaps to superintend the work of manufacturing radio telephones which had begun in earnest in the Newark plant.

As deForest sailed for New York he had a feeling that the radio telephone had at last "arrived"; that the sanction of the great governments of Europe had given it the recognition it needed; that hereafter the way would be smooth. He delighted in this sensation, for to him a sense of security was nothing if not a rare emotion. The city which he was nearing would soon show him whether or not this happy feeling was justified.

THE recognition which his European achievement had amply warranted awaited him back in New York. The Radio Telephone Company was forging ahead. Executives and laboratory men alike now got behind deForest in his determination to construct the most powerful telephone transmitters that could possibly be constructed at that time, in order to convince the British Admiralty of the practicability of the deForest radio telephone. The powerful new radio telephones were completed in September and deForest again departed for Europe in the autumn of 1908 to demonstrate his new apparatus.

And again all seemed to go well with him. The spell of good luck had not yet broken. On the trip across, deForest occupied himself with an intensive study of the new science in which he was at work. At this time he was employing the arc as a generator of undamped waves but he had already begun to study the characteristics of the newly discovered "quenched spark gap." After all, the arc was by no means perfect. It was still unsteady and needed constant watching; and it still needed a separate generator to furnish its supply of current. Here was a problem still unmastered. While other passengers idled away their time and tried to forget the feverish activity of the city, deForest pored over German and French text-books dealing with the characteristics of this new device, "the quenched spark gap," which promised to be so efficient a generator of radio waves.

At London the lords of the British Admiralty seemed more or less ready to be convinced, and deForest, with his able young wife as assistant, stood ready to convince them. Before he started his experiment he con-

versed with these notables at some length, pointing with pride to the behavior of the radio phones aboard Admiral Evans' fleet while that fleet was passing through the roughest kind of weather, and how the commanding officers had guided the flock of destroyers through the Straits of Magellan by simply talking into a telephone transmitter. He showed them the newspaper stories of Bob Evans' own account of his new marvel, the radio phone, which he declared heightened his pride in his fleet, and which he considered a boon to humanity.

Then he set to work. The demonstration was highly interesting and satisfactory. Voice communication was maintained between H.M.S. *Vernon* in Portsmouth Harbor and the cruiser *Furious* up to a distance of sixty miles, which was more than four times what the Admiralty had expected. Dr. and Mrs. deForest, who had been conducting the experiments together, were thoroughly satisfied with what they had done, and not in the least surprised to learn that the Admiralty was purchasing these two sets of equipment. It had turned out just as deForest had hoped.

Then arose the question of the order to equip the fleet, and the cycle of good fortune was done. DeForest found that the Admiralty was "unable to place the order at present." There were political implications. After all England was Marconi's territory. The British Marconi Co. was apparently functioning now as ever. DeForest failed to receive the order, in spite of his brilliant demonstration. He and his young wife returned to America, where, or so the inventor believed then, the chances of failure were not so great.

VII

The sense of his own fate, which by this time had become a highly developed characteristic in deForest, had already warned him of what was to come. The Radio Telephone Company's long list of accomplishments, including wireless telephones recently set up, and now functioning perfectly in Cleveland, Toledo, and other land points was facing its old problem. It was short of funds. The plant in Newark that had recently hummed with the manufacturing of more and more powerful radio phones was closed down. Just at this crucial point in the history of radio, all operations might indeed have been suspended had not the imagination of deForest been inflamed by his European conquest.

He was at this time a man of thirty-six years, fifteen of which had been spent in achievement of one kind or another. He was weary of never-ending money troubles; tired of building up new organizations for whose growth he was so willing to struggle and to create, only to have them decline and fall back upon his own shoulders. To what end? There was a constant succession of debacled organizations. Experience had taught him to cleave out for himself a path to follow, and now

instinctively he began to traverse the one domain where existed peace and exhilaration and the glory of work. The inventor turned his back upon the cares of a work-aday world as he felt anew "that motive force like in kind to that which drives the dweller in noisy confused cities to restful Alpine heights whence he seems to have an outlook on eternity."

At this time deForest was not to be satisfied with mere inventions and devices. He wanted to send his idea of the radio telephone farther out into the world than it had ever gone. He wanted to span the Atlantic. It was while working in the Eiffel Tower that the idea had first come to him. The Metropolitant Life Insurance Company's Tower that had faced the old Parker Building laboratory was then the tallest structure in America; the Eiffel Tower was the tallest in Europe. These two great buildings were the finest of their kind in the old world and the new. He had just at this time opened a wireless telegraph and telephone station on the Metropolitan Life Tower, and working high up above the city's noise, even as he had in the Eiffel Tower, the desire to span the distance, first by telegraph, then by telephone, became too strong to resist.

Despite his crippled finances, he began slowly but determinedly to work out his idea. As a result of his brilliant success in France the preceding year it was not difficult to enlist the coöperation of the French government with a view to establishing direct wireless communication between New York and Paris, a feat that had not yet been dreamed of by any but deForest. The difficult task of erecting antennæ was begun early in 1909. The antennæ remained aloft for about one year.

Late one night in the following winter shortly after he had redesigned and improved the original structure, deForest left his barely completed job to find that traffic was halted in the street outside by a sudden but terrific sleet storm, the worst in the winter of that year. He wondered: how would this affect the antennæ? In other words, would it halt his dream? The answer was soon in arriving. Next morning the owners of the Metropolitan Building greeted him with the information that one of his antenna wires on top of the tower had fallen during the night, barely missing a pedestrian on Twenty-third Street. They flatly refused to let the antennæ go up again. Horrified beyond words at this turn of affairs, the inventor found an even worse situation awaiting him in the tower. Ice had formed on his wires more than an inch thick, bringing them all down. The project was abandoned or (phrase of even more tragic portent) it was put off.

Those who had scoffed at this brave dream of sending a voice across the ocean were quick to make the most of the situation, putting to naught the inventor's prophecy. Nevertheless deForest kept at it and, as a matter of fact, radio communication was established between Arlington, near Washington, D.C., and Paris in 1915, just six years after deForest made his prophecy to a skeptical world.

MEANTIME deForest had moved his laboratory, which was at once workshop and headquarters, from 14th Street to a building at 103 Park Avenue. The various problems of the radio telephone still confronted him. He wanted to increase the power input available to the

set—until this time the maximum consumption had been a little more than one-half kilowatt—and to solve the old problem of modulation. As soon as the new laboratory was installed at the Park Avenue Building, deForest began the installation of a fine antenna on the top of the structure, to project voice and music as far as possible, to set at least a new milestone in the radio telephone experiment.

The company had erected a 125-foot steel tower on the roof of the building. DeForest rigged a six wire antennæ from the tower down into his laboratory windows. He had now made up his mind to broadcast.

For the first program he called one of the most famous sopranos of the Hammerstein Manhattan Company, Madame Mazarin, who graciously consented to come to his studio, and sing into the microphone an aria from "Carmen." The program met with a great reception. DeForest's broadcast transmitter was indeed making radio history. Some time later deForest's mother-in-law, Mrs. Harriet Stanton Blatch, gave an interesting talk on women's suffrage, marking the use of the ether for the first time for propaganda. Yet only a small number of people, amateurs and specially arranged groups, heard these broadcasts.

DeForest could not stop there. He had tasted the flavor of greater things. He thought of the idea of broadcasting grand opera. It would be perfectly possible to put an opera on the air for the benefit of the listening few, and highly interesting to ascertain just how many were listening and how great their interest was. Since he had learned that it is always easier to see the big people, just as it was for him easier to do the big things, he went for his talent to the Metropolitan

Opera House. At that time Andreas Dippel was co-impresario with Gatti-Casazza, but it was to Dippel that deForest first went to present his idea. Dippel saw the possibilities of the idea at once and made the necessary business arrangements with deForest during their first interview. It was a thrilling prospect. Andreas Dippel was almost as enthusiastic as deForest.

DeForest saw, beside the picture of a public-spirited inventor sending grand opera out to the world, another and very different picture. In this picture a hungry-looking boy was mounting the steps to take his twenty-five cent seat high up under the eaves of the Chicago Opera House. He wanted to hear the music so much that at times the quarter he spent was the last quarter he had. That was only fifteen years ago. He was going to the opera again now, but he was actually going as some part of it. As he thought over and over again of what he was about to do — he was so sure of his success that the problems of how to succeed did not enter his mind — he hoped that some day young men and boys who wanted great music even as he had wanted it back in Chicago would have it sent to them wherever they were, through the medium, radio, that he had helped to make possible.

Strangely enough everybody else seemed ready and willing to coöperate. Two microphones were used, one on the stage and another in the wings. The first program was one of the Metropolitan's double bills, "Cavalleria Rusticana" and "Pagliacci," with Caruso appearing as Turridu in the former. A little half-kilowatt telephone transmitter, through which the chief arias were to pass, was installed in a vacant room at the top of the Opera House. The antennæ were suspended from

two bamboo fish poles, the tallest obtainable, and led down into an attic just off the ballet rehearsal room. Listeners-in were stationed at the Park Avenue laboratory, at the Metropolitan Life Building and at the Newark plant, supplemented by many curious engineers and amateurs and a specially invited audience at one of the hotels in the Times Square district.

In spite of the crude arrangement, crude indeed by contrast to the present day elaborate broadcast studios, Caruso's voice went out over the ether on that date memorable in the history of radio, January 20, 1910, and was heard by perhaps fifty listeners. Wireless telephone operators in ships in New York harbor and nearby waters, and at the Brooklyn Navy Yards, and a group of newspaper men who had gathered with great interest in the factory in Newark, all were lavish in their praises of the reception. DeForest's idea had materialized into a public event. The inventor felt convinced from that minute that broadcasting was destined to go forward, perhaps even as far as his own wild dream of uniting the scattered corners of the globe.

At just about this time the word "radio," heretofore a mysterious "force" that only the scientists understood, sprang into being. It was ushered in by a motley group of people, mostly boys and young men, working all alone on crude homemade apparatus in the isolation of their own homes. These young people scattered over the country were engaged in the strange pastime of "fishing" things out of the invisible space about them, at first dots and dashes and later words and music that came from nowhere. A mystic jargon sprang up, a

jargon that parents did not in the least understand. There was talk of "variable condensers," "inductances," "crystal audion detectors," "head sets," "spark gaps." Parents, at first indulgent of the strange and not inexpensive devices their youngsters brought into the home, began to gape in wonder as they donned the head sets, and actually listened to music coming to them out of the air. They did not in the least understand how it happened. It seemed mysterious beyond words. Their amusement died out as they found themselves listening to an explanation of the vast intricacies of "radio."

These young amateurs, working in isolation upon the crudest kind of apparatus, had become an important element in the plans of Lee deForest. As far back as 1909 he had realized the existence of a scattered group of young people who were watching his movements with something akin to fascination. They wanted to know about inductances and condensers; how to put the sets together; how to get the best "reception." They did not care if the signals, the music or whatever they finally fished out of space was weak and accompanied by all sorts of strange noises. They were in the thing for the fun of the game. That was the kind of spirit that Lee deForest had been looking for in other people all his life.

Even at that time, from the constantly increasing number of scribbled notes, telegrams, and once in a while a brave young visitor in person, deForest had begun to realize the importance of these young "fans" who by their enthusiasm and persistence might well sponsor a great industry. He read each and every one of the little notes of inquiry sent by boys all the way from the farms of Oakland, California, to the city

apartments near his laboratory, glad indeed to know that somewhere else in the world was the same pioneering spirit that had animated him as a boy back in Talladega, the spirit which is in a measure that of eternal youth. After all his struggles to move the minds and imaginations of settled people, it reassured him to know that the idea of fighting for the glory of the fight was still alive in the world!

Now the Radio Telephone Company opened its doors to the amateurs, inviting them to visit its store or show room to watch demonstrations and to purchase equipment in the tower of the Metropolitan Life Building. News of the new enterprise spread like wildfire among the radio fans and amateurs in and around New York City. Hugo Guernsback, outstanding pioneer in the field of radio journalism for the amateur, began to write about the demonstrations in the Madison Tower in a paper called the "Wireless Experimenter." The complete audion receivers of those days were similar to those originally designed for Admiral Evans' battleships with head sets and pancake tuning coils. One of deForest's early engineers, Quincy S. Brackett, showed these youngsters how to put their sets together, the first of an army of salesmen which today numbers thousands.

Boys and young men, sometimes accompanied by their parents, but more often alone, flocked into the show room in increasing numbers. DeForest himself tried to be on hand as often as possible, for the sight of these enthusiastic youngsters gave him an added sense of encouragement and achievement. The inventor himself has explained in his own words just what it meant in the early days of radio to have this group of

young pioneers behind him, watching for his programs with the greatest eagerness.

"I can hope for no greater success in life than to have it truthfully stated that my life epitomizes the spirit which has animated the American Amateur in Radio from the beginning; his desire to explore the ether, to communicate over great distances without wires, to originate and construct his own apparatus for the fun of the game and interest in science and incidentally the good which his game has worked for humanity."

It was these boys and young men who caught the first faint strains of music coming over the ether bands that, although they were heard only by the radio amateurs and ship operators at sea, still marked the beginning of an industry that has expanded from the 60,000 listeners-in who built their own sets to catch the election returns in 1920 to the 50,000,000 who received election returns in 1928. Just as deForest had prophesied, it was the American amateur, working in isolation on his crude homemade apparatus, who, because of his enthusiasm and persistence, helped usher in a new industry.

VIII

It would hardly be fair to pass on to the public development of radio without explaining just what deForest, who is first of all an inventor, forever on the search for new ideas, was doing to improve the technique of transmission and reception.

Following his great success in France and Italy, the Army had ordered the improved wireless telephone and telegraph sets to be installed on the two trans-Pacific transports, the *Dix* and the *Buford,* plying to Honolulu and the Philippines. DeForest, who had taken with him his invaluable assistant, Frank Merriam, had made his way first to Seattle to equip the *Dix,* and next to San Francisco, to equip the *Buford.* These installations were the first of the "quenched spark" telegraphy, a system destined to become famous, and that is indeed worthy of attention. This was June, 1910.

It was during his visit to Berlin in 1908 that deForest had first made the acquaintance of Doctor Georg Seibt, a radio physicist of considerable note who had been one of the experts of the Telefunken Company, and who was, incidentally, one of the foremost exponents of the new quenched spark system, a method of transmission that was a vast improvement upon the old open spark

method. DeForest immediately saw the advantages of Seibt's system and, since the German engineer was anxious to come to America, at once made a contract calling for his services for two years. Whereupon Seibt came to the Park Avenue laboratory in 1908, bringing with him all his ideas on quenched spark telegraph transmitters.

These two modern-minded engineers, together with their three able assistants, Emil J. Simon, Fred Kolster and George Lewis, began to accomplish great things. Through the years 1908-09 the quenched spark transmitter rapidly proved itself to be vastly more powerful and penetrating than the old-fashioned spark telegraph which had been used exclusively up to that date in America and with which the Marconi Company was still struggling. A quenched spark transmitter was placed in the Metropolitan Life Tower station where it was connected to an aerial six hundred feet high, the tallest in America at that time. It began to be heard all over the eastern part of the United States and far out to sea, although the power behind it was only one kilowatt. As a result of the extraordinary work of this Seibt-deForest quenched spark transmitter, the Army and Navy became for the first time greatly interested in this new development, resulting in the contracts from the United States Signal Corps to equip the *Dix* and the *Buford*. It need hardly be added that deForest had already equipped all his stations at Philadelphia, and on the Great Lakes with the new type of telegraph transmitter.

The new system began to smash all long distance transmission records. Traffic was started and continued between the Chicago and Milwaukee stations and the

Metropolitan Tower in New York. The first time the equipment was tested on the *Dix* in the harbor at Seattle, the signals were picked up in Honolulu. The question of static, of course, was as puzzling as ever, but Seibt and deForest, knowing from deForest's early work at Armour Institute, and during the 1903 yacht races, that the radio signals could be read much more easily if the note of the transmitted signal were of a high pitch, set about designing a five-hundred-cycle generator to go with the new quenched spark gap. When the first two generators were finally set into full operation, the results were astounding. Through his knowledge of the early development of the gap, Dr. Seibt understood its working thoroughly and so, together with deForest, had designed a transmitter whose gap could be adjusted to give the clearest tone to the signal put on the air.

But notwithstanding this splendid work, orders which the company had expected from the Army and Navy, were not forthcoming in sufficiently large measure to keep the radio telephone organization going. It was deForest who suffered most. After months of struggle in San Francisco and Los Angeles, during which he established a regular service between the Phelan Building in San Francisco, and the Hellman Building in Los Angeles, over which a large amount of paid traffic was handled, he found himself without funds and the New York office unable to send him any. The situation was doubly discouraging after his recent brilliant achievements. Still expecting his company to recover, deForest sought employment in San Francisco with the Federal Telegraph Company, a company which had been organized two years before to develop and exploit

the Poulsen Arc Telegraph System in the United States. During his stay in San Francisco, deForest had become a close friend of C. F. Elwell, the chief engineer, and it was Elwell who arranged to give him employment as research engineer for his company.

DeForest learned with some measure of consolation that he would live and work in Palo Alto, a lovely university town about thirty-five miles south of San Francisco. Word came from the East that his company, the Radio Telephone Company, for which he had worked so long and hard, was rapidly failing. In the peace and quiet of the university town he found it much easier than he had anticipated to live down the bitter disappointment of seeing his second hard-won enterprise pass out of the picture. After all, deForest was a scientist, not a business man, and the knowledge that he could work uninterruptedly on his ideas was always a source of joy sufficient to numb the pain resulting from the slow demise of his toil-won successes. The entry in his notebook tells the story concisely enough.

"About this time, however, bad management and other difficulties on the part of some of the directors of the Radio Telephone Company brought an end to our plans. I therefore decided to remain in California with the Federal Telegraph Company and continue the development of several inventions in which I was particularly interested. As a result of this connection three of my happiest and most useful years were spent in California. My work was chiefly experimental; my laboratory at beautiful Palo Alto; but the installation of receiving apparatus and various new devices in connection with the Radio Telegraph gave me opportunity to travel up and down the Pacific coast and make observa-

tions on the reception of undamped wave telegraph signals which were exceedingly interesting."

Relieved, at any rate, of the constant problems facing his company, deForest threw himself whole-heartedly into laboratory experiment, determined at last to solve some of the more pressing problems which faced the further development of the Poulsen Telegraph system, particularly the most recent method of high speed transmission. It was in this particular and highly specialized field of invention that he made many interesting and valuable improvements, directed towards high speed telegraphing, and to the sending of more than one message simultaneously from the same transmitting station.

In this fascinating work deForest was ably assisted by a young engineer and inventor, Charles V. Logwood, who possessed a veritable genius for the solving of wireless telegraph and telephone problems. At that time Logwood had just invented the "rotary tikker," which proved to be a thoroughly reliable and very much more sensitive detector for undamped wave signals than the European tikker of Poulsen and Pedersen. DeForest marveled at the simplicity of this device of Logwood's and the ingenuity which it represented, but he was soon to discover that these were the obvious characteristics of Logwood's genius. For Logwood was gifted with inherent inventive talents of an unusual order which, unlike the talents of many another engineer with whom deForest had worked, were never dulled or suppressed by a technical engineering schooling. Many years later, after a long and delightful asso-

ciation in invention, deForest himself wrote of Logwood, some time after the latter's death in 1927:

"In all of my radio experience I have never come across anyone who was so sure to work out, and so quickly, almost any problem which was put to him. Personally he was one of the most likable chaps I ever met, kindly, friendly, open-minded, never stubborn or conceited. His untimely death means a great loss to Radio, and he will be mourned by a wide circle of friends and associates who have known him personally, or who have heard of his numerous contributions to the engrossing field in which he was, as early as 1906, a pioneer."

Logwood had never seen an audion until deForest showed him one, but he immediately fell enamored of its astonishing simplicity. He began to foresee endless possibilities for this device. Logwood and deForest, their minds already afire with new ideas that they yearned to put into experiment, were shortly joined by another engineer, Herbert Van Etten, who had been employed with the Pacific Telephone and Telegraph Company in San Francisco, and who had the keenest interest in the problems that deForest and Logwood were attacking at that time in Palo Alto. These three engineers began a "research magnificent" in radio. They turned their minds upon the problem of high speed telegraphy, multiple transmission, static elimination, and improvement of the range of the telegraph by improving the detector and amplifier of the Federal Telegraph Company's system.

In the summer of 1912, Elwell, the company's chief engineer, went to Honolulu to establish transmission between San Francisco and that point, leaving the details of laboratory work, as well as invention and

refinement of the many problems on hand, almost entirely to deForest. Whereupon, Logwood, deForest and Van Etten, by now a powerful combination, entered upon a line of experimentation which was destined to become historic in its far-reaching consequences.

The first of these was chiefly deForest's accomplishment. Upon one of the installations for the company a new phenomenon had come across his horizon: he had discovered that there was such a thing as "fading." Signals at one moment came in strong, then gradually faded out. DeForest put his hand on the condenser dial in the hope of retuning the set, but as soon as his hand approached the dial the signal came back, and while he was still considering this the signal faded out again. There could be but one explanation of the behavior of the set. There was some uncontrollable condition in the atmosphere or the ether which was causing the signals to swing in that manner. It was *fading*, a term now well recognized in Radio, but then for the first time observed. Whereupon he prepared a paper for the Institute of Radio Engineers in which he set forth for the first time the idea of interference between two portions of the original wave-train due to refraction or reflection of that portion which took the upper course through the atmosphere upon some body of vapor, or heated, or ionized air. And this explanation of deForest's of the phenomenon known as fading is today generally recognized as the correct one.

Then came the problem of constructing a high speed transmitter and receiver. DeForest began to look for the solution of this problem along an entirely new track. He went back some years in his experience and recalled the telegraphone, a device which had been patented for the

reproduction of dictation, and consisting of a fine steel piano wire running in the field of an electro magnet. . . . He now began to develop the audion amplifier in connection with the steel-wire telegraphone, and constructed for the transmitter a simple high-speed telegraph key, pneumatically operated by a punch tape which was driven through the transmitter machine at a high rate of speed. This combination of pneumatic key and punched tape, operated the Poulsen undamped wave transmitter, while the receiver utilized the Rotary Tikker and audion amplifier — this last recording the amplified signals on the steel wire of the telegraphone. By these means he was able to transmit up to ninety words a minute between the San Francisco and Los Angeles stations of the Federal Telegraph Company.

Then deForest, Logwood and Van Etten began their research on the audion. It was the summer of 1912, and the three engineers were left more or less to themselves, free to follow out whatever ideas they chose and for as long a period as they wanted. It was the first time that deForest had ever enjoyed such complete leisure for experiment, the first time in his life that he had not been bothered with a hundred and one petty details that had nothing whatsoever to do with his experimenting. The result was the discovery of the enormous amplifying possibilities of the audion in cascade, the very device for which telephone engineers had been vainly searching for the past twenty years.

It was in July, 1912, that deForest for the first time connected up first two and then three audions in cascade arrangement, and used them as a telephone repeater or relay. The principle involved sounds simple when put into words: the output of the first audion tube was fed

into the input of the second; and the output of the second was fed into the input of the third. The audion tube at that time had an amplification factor of about three. This means simply that the telephone signals, or currents coming out from the first audion were three times as powerful as those going into it, and so on with the second and third audion. Therefore it was found that the amplification between the input of the first audion to the output of the third was 3 x 3 x 3, or twenty-seven times.

Through the spring and summer of 1912 these three engineers continued to experiment at great length with this arrangement, designing and constructing various forms of the telephone transformer, choke-coils and various other devices, in an effort to secure the maximum possible amplification effect of the telephone signals.

In exultation over his discovery deForest immediately wrote a full description of his experiments, and the results of each, to his friend John Stone, who had formerly been one of the research engineers for the Bell Telephone Company and who was at that time in New York in very close relations with that organization. Stone was intensely interested in deForest's discovery and wrote at once for further details. His letter stated that he could without doubt interest his friend, J. J. Carty, then chief engineer of the A. T. & T., in the audion amplifier for use on long distance telephone lines. DeForest must make arrangements at once to bring his apparatus with him to New York to give the demonstration for which Stone was already arranging. The loyal engineers who had watched this discovery materialize in the quiet of the laboratory in Palo Alto gathered

round to congratulate the inventor. The idea might well revolutionize long distance telephony. DeForest himself believed that here he had at last put an end to the troubles that had thus far overshadowed his whole existence.

BEFORE deForest left for New York, however, the "research magnificent" rose to a brilliant climax. There in the little Palo Alto laboratory, while continuing their experiments on the audion amplifier, deForest and Van Etten observed that when they attempted to make one audion tube do the work of two, *i.e.,* when they connected the output circuit back into the input circuit, or when the coil in the output circuit of the audion was located close to the telephone coil in the input circuit, a clear whistling note was heard in the telephone receiver which was always connected in the last output circuit. This result, in the light of present-day knowledge, was perhaps to be expected. At that time, however, it was a queer piece of business, sufficiently startling to investigate. What deForest had now discovered was the "feed-back" principle which has proven to be the basis of all modern radio telegraph and telephone transmitters, as well as the principle of all modern heterodyne receivers. This discovery of the "feed-back" fascinated the three engineers. They played with it in every conceivable fashion. For a time they even lost interest in developing the cascade audion amplifier to investigate further this novel idea.

IX

It was a different deForest who came on to New York in September of 1912, his cascade audion amplifier carefully packed in a trunk and shipped on by express before him. In the first place he was accompanied in his journey by the President of the Federal Telegraph Company, Beech Thompson, whose sincere interest in, and admiration for, the inventor's most recent discovery alone would have kept deForest buoyed up, even had he not enjoyed the added excitement of the promise that lay waiting for him in New York. For the first time in two years he was visiting the city whose changing streets and buildings had watched the rise and fall of some of his dearest dreams, a city of associations and memories, of victories and defeats. It would mean renewing old friendships, visiting long familiar spots. But aside from these surface pleasures, deForest had enjoyed for the first time in his life those "Alpine heights" of uninterrupted experimenting behind the walls of his laboratory. This period of creation had unloosed from his mind the ideas with which he had long been burdened, and these very ideas were now leaping out of his hands into public acclaim. It was a different deForest because,

whatever happened, he had done at last what he had wanted to do.

Arrived in New York he went straight to the National Arts Club in Gramercy Park where John Stone was eagerly waiting to hear the story of the amplifier and the oscillating audion. Stone could hardly wait to hear with his own ears, so deForest arranged a private demonstration in the attic of the club where Stone made his residence. Stone heard, saw—and believed. He felt proud that the other inventor had called upon him to help promote this remarkable discovery which, as he said, needed no promotion, for it was a device of which the engineers of the telephone company were badly in need. Once the demonstration was staged, deForest's financial future would be an established fact, for the executives of the company could not possibly offer less than $500,000 for such an important device.

After the customary number of setbacks, the day set for the demonstration finally arrived. DeForest took his paraphernalia into one of the large laboratories of the Western Electric Company on West Street. There were present the representatives of the technical staff of the Telephone Company and the Western Electric Company to watch his first public demonstration of the audion as amplifier of weak electrical currents. As he worked a heavy air of discouragement seeped in to him from the bored and weary engineers. He had noticed upon entrance that only five had apparently thought the experiment of sufficient importance to attend, and these had the attitude of being there only because they were ordered to do so. Their expressions seemed to say: "Here is just one more of those telephone repeating

devices which have been submitted to us by crazy inventors for years past."

DeForest went on with his demonstration. He showed the use of a single stage, two stages in cascade, and finally the three-stage adaptation. As the men saw the results which he achieved, their attitude changed. They began to ask questions. The new scheme of amplification they thought, just as Stone had prophesied, showed promise of revolutionizing the current practice in long-distance telephony. But they didn't say this to deForest. Only the minor engineers volunteered comment, but deForest, who was to return next day for another demonstration, left feeling cheered by what he had heard.

The second day, the room was crowded with engineers, prominent among whom were Drs. Arnold and Colpitts. In contrast to the indifference of yesterday, their faces now showed the keenest interest. After the demonstration the engineers plied deForest with pertinent questions regarding the voltage, the impedence of the device, as well as his idea of the theory on which it operated. Dr. Arnold informed deForest and his friend Mr. Stone that the company was definitely interested; that deForest should leave his apparatus with them; that they would carry on further investigations with the device; and that deForest might expect to hear from them shortly.

As Stone and deForest left the laboratory, they were both in the highest spirits. Stone congratulated deForest for having put the thing through all sorts of antics at the behest of the technical men. In six or eight weeks at the very latest, he would surely receive a handsome offer from the Telephone Company for the use of his

amplifier. Meantime it was simply a problem of waiting. He would settle down to some of the problems that had haunted him in his days with the Federal Telegraph Company, problems that would easily consume his attention until the conference with the Telephone Company officials should be announced.

TIME passed, and nothing happened. And at the end of eight long weeks, deForest had heard not one word from the Telephone Company. He was at a loss to understand what had happened to the engineers who had examined his device with the greatest eagerness and declared their company "definitely interested." Stone found the silence equally baffling. There was no doubt but that the company was in need of the audion amplifier. Why, then, had they made no offer? The eight weeks stretched into three months.

At length deForest wrote to J. J. Carty, asking for some explanation and suggesting, naïvely enough, that any further demonstration or information would be given gladly, if the engineers were not yet convinced of the practicability of the new device. An answer came. It said that the engineers had not yet completed their investigations and hence had come to no decision on the matter.

Nowhere in the gloomy realm of his association with big organizations had there been a duplicate experience. Never before had he been the master of such an apparently simple and sure situation, only to find himself entirely on the outside, without the remotest idea as to what was transpiring. He shook his head in wonder.

Another letter came. It was from the Federal Tele-

graph Company and it said that deForest could not expect that organization to pay his salary — his sole means of livelihood at that time — if he remained longer away from his laboratory at Palo Alto. There was no way out. He determined to go back.

And even in his personal life affairs had not gone smoothly. The cycle of luck had broken down here also. Long before deForest had left New York for San Francisco his brief domestic tranquillity had terminated. Notwithstanding the birth of a little girl, Harriet Stanton deForest, an estrangement had separated the two parents, and finally resulted in divorce while the father was living in California.

DeForest's long and futile stay in New York following his demonstration before the telephone engineers, might indeed have made him miserable — had not an adventure happened to deForest. He had met and fallen in love with a young lady whose name is far from unknown in musical circles here and abroad, Mary Mayo, who was then singing in Ina Claire's starring vehicle, "The Quaker Girl." DeForest at once decided to take Miss Mayo back to Palo Alto as his wife.

So again the little California town brought peace and even happiness in place of the harassment of the Eastern city. The engineers at the Federal Telegraph Company laboratory welcomed him back. And grateful again for his interlude of experiment, deForest threw himself into the all-absorbing laboratory development of the amplifier and oscillator. In April, 1913, he succeeded, for the first time in radio history, in using the audion as a heterodyne detector of undamped wireless telegraph signals. This heterodyne audion detector was destined completely to displace the tikker, which had up to that

time been used everywhere in connection with the Poulsen Arc transmitter. At the time he gave the first description of the oscillating audion to John Stone, he told fully of the method and even showed how the pitch of the note could be changed with a variable condenser in one of the tuned circuits. On April 17, 1913, at the San Francisco station of the Federal Telegraph Company, he received and copied the signals of the Palo Alto station and called in the engineers of the company to witness the feat.

But no matter what happened in Palo Alto, in spite of the peace and progress that had been his experience in the charming little town, the urge for his own work in his own name was forever present. That would mean returning to New York and refinancing the Radio Telephone Company, his own organization that, whatever the difficulties it had caused him, was still his own. He was confident that it was only a question of time before the means of, or reason for, returning to the city would come his way.

X

He was right. The early part of May, 1913, found him returning East, ostensibly to consult with two financiers, one Dr. Louis Duncan and another Sam Young, whom he had met while in New York demonstrating the amplifier for the telephone engineers, and who purported to be interested in the commercial development by deForest of his amplifier with the telegraphone arrangement attached to a motion picture machine for the production of talking motion pictures. Even at that time, deForest believed that this combination would make feasible talking pictures, and since none of the devices developed up to that time for use in telephony were suitable, the deForest amplifier looked like the missing link in the scheme. DeForest had, they thought, a simple and apparently practical idea. It was to use the telegraphone record, which was a piano wire with a magnetic record of the musical vibrations, as an adjunct to the film with the pictures. Through this method perfect synchronism could be secured. The chief trouble was, of course, the reproduction of the music in proper volume and with proper timbre.

DeForest proposed to Duncan that he supervise the production and reproduction of the new talking motion

pictures at the old Biograph Studio on 14th Street, where he had secured laboratory space. To do this required a complete change in his affairs. It meant giving up his connection with the Federal Telegraph Company; burning all his bridges behind him for the third time. It was a gamble. He took it. After all, he reasoned, no matter what happened to his talking picture scheme, it could not be many more weeks before the Telephone Company would offer and pay a handsome sum for the audion amplifier rights for telephone purposes.

The routine established in deForest's life long ago continued in effect at the Biograph Studio. The results of his experiments were all encouraging; and in equal proportion his finances were low indeed. The fact that the promoters had little resources was soon revealed. Meantime there was no word from the telephone company. Month after month dragged by. DeForest saw himself threatened with a penury that was reminiscent indeed of the early days. Only this time he had a wife to care for. In a frantic effort to ward off this horrible state, he wrote again to J. J. Carty, hoping to obtain some word to carry him through. The answer came back; perfectly worded and pefectly hopeless. It said that he, Carty, had nothing to say in the matter. It was entirely in the hands of the Supervisory Board and deForest must await their decision.

Meantime from all sides came the signs of impending disaster. One March day in Palo Alto back in 1912, deForest had been called from his laboratory by a stranger who informed him that he was a United States Marshal, and that he had a warrant for Lee deForest's arrest. The charge was that of using the mails to defraud. In consternation deForest had telephoned the

president of the Federal Telegraph Company, Beech Thompson, in San Francisco and explained his plight. It seemed too good to hope that comparative strangers would come to his defense and save him from jail. Thompson nevertheless rose nobly to the occasion and between five o'clock, the hour of the frantic call, and nine o'clock, he had succeeded in releasing deForest on a $10,000 bond. And now, fifteen months later, while the inventor waited hopelessly for his answer from the mighty American Telephone and Telegraph Company, and while his resources dwindled to nothing, the dread uncertainty of when and where he would face trial before the Federal Courts was hanging over him.

Thus the summer of 1913 found deForest in dire straits. He was penniless and desperate. One day, alone in his laboratory in the old Biograph Building, the card of a man whose name he did not recognize was presented to him. He asked the boy to show him in. A dapper young man appeared before him. The weary inventor watched him with interest, for he was good-looking, well-dressed, and he had a pleasant suave manner of speech. The young man said that he was an attorney, but considerable time elapsed and considerable conversation took place before deForest discovered what he really wanted. It seemed the latter was interested in the Audion Amplifier.

"In fact," said he, with a smile, "I believe I have a client who is willing to pay well for its use."

DeForest replied that the American Telephone and Telegraph Company had the audion patents under consideration and were very favorably impressed with the operation of the device as a telephone repeater. The young man smiled again, and nodded his head. Then

deForest was struck with an idea. There was something altogether mysterious about this visitor.

"Are you, by any chance, connected with the Telephone Company?"

"Not in any way whatsoever," he replied, and seeing that deForest was still dubious, the visitor suddenly assumed more dignity than he apparently possessed, and said, "I give you my word of honor as a gentleman."

Upon this assurance the attorney proffered his hand and deForest, who naïvely believed that he was a gentleman who had a word of honor, simply because he had said so, took his hand.

"I cannot divulge to you the name of my clients," continued the young man. "But I can tell you that they are interested in obtaining the patent rights to the Audion Amplifier for wire telephony only."

In all facts concerning the affairs of deForest, the man was curiously well informed and willing to reveal his information. It seemed that he had gone first to deForest's old associates in the Radio Telephone Company and learned there of the inventor's whereabouts and situation, information that was not at all difficult to obtain. He informed deForest suddenly that he had also seen the other directors of the company and informed them that his anonymous clients had $50,000 to pay for these rights, and that they would pay not one dollar more. DeForest replied that such a price was out of the question.

"Not when you come to consider the financial situation of your Radio Telephone Company," replied the attorney. "I know that it is soon to be sold out for debt to the State of New Jersey. Hadn't you better

accept my offer rather than let the patents go to the auction block where they will be sold for a song?"

With this parting bit of inside information, the mysterious young man took his leave. DeForest was mystified as he thought the matter over. There was something sinister about the interview, in spite of the young man's air of conviction and honesty. Yet, if he were to judge from the attorney's manner, the deal was apparently entirely honest. The young man had even explained away the offer of $50,000 by saying that his client was in the business of expanding and hence could not spare more than this amount without jeopardizing future operations.

The situation, whatever the undercurrent of complications and intrigue, resolved itself simply. The sum of $50,000 was ridiculously small, but deForest and the Radio Telephone Co. needed it badly. As much as he dreaded accepting a price one-tenth the worth of the rights, deForest realized that it was the one alternative that faced him and what remained of the Radio Telephone Company. If only he could afford to wait!

So a stockholders' meeting was duly called, and the $50,000 offer was duly voted on and accepted as the only way out of an otherwise hopeless situation. All the officers of the company signed their names to a document assigning the exclusive right to seven deForest audion patents for wire telephone and telegraph purposes to the young attorney. The $50,000 was duly paid over and deposited. The reborn Radio Telegraph and Telephone Company became a live organization. DeForest felt relieved, if not happy, about the deal. He wired his friend Logwood to come to New York and continue with him their experimental

work. A new laboratory was fitted up at Highbridge, on the Harlem River, and began to hum with activity. DeForest's attitude of suspicion towards the strange young attorney disappeared completely in the new hope the deal had brought.

But in the midst of the excitement of new activities, a strange story reached deForest's ears. It concerned a record purported to have been seen in the United States Patent Office, dated just six weeks after the execution of the deal with a party bearing the same name as the attorney who had purchased the patents that showed a transfer of these licensed rights to the audion amplifier to the American Telephone and Telegraph Company. DeForest recalled the suave, good-looking young man, with his honest manner and his outstretched hand and his "word of honor as a gentleman."

The inventor's mutilated belief in the ability of great organizations to deal squarely with individuals perished completely when he heard a rumor long afterwards, that the accountant handling the private books of the American Telephone and Telegraph Company had turned $450,000 back to the general account from the "Audion Amplifier Fund." For $500,000, it was stated, had been voted by the Board of Directors for the purpose of purchasing the patent rights on the audion amplifier of Lee deForest, should that amount prove necessary to effect the transaction!

XI

DeForest's normal energies were just reasserting themselves, his interest in the idea of broadcasting stronger than ever, when the dread shadow under which he had lived and moved for so long leapt suddenly into reality. The hand of the law of the United States clamped down on him, on his good friend and patent attorney, Captain S. E. Darby, who had been a director of the Radio Telephone Company for years, and on two other directors of the company, J. D. Smith and Elmer Burlingame. The four men learned they were to be put on trial in the Federal Court of New York City on November 12, 1913, charged with using the mails to defraud the public by selling stock "in a company incorporated for $2,000,000, whose only assets were deForest's patents chiefly directed to a strange device like an incandescent lamp, which he called an Audion, and which device had proven to be worthless."

Furthermore, the Federal District Attorney informed the judge, during the course of his attacks on the inventor, against whom he showed an especial animus, "DeForest has said in many newspapers and over his signature that it would be possible to transmit the human voice across the Atlantic before many years.

Based on these absurd and deliberately misleading statements of deForest, the misguided public, Your Honor, had been persuaded to purchase stock in his company, paying as high as ten and twenty dollars a share for the stock." The learned District Attorney ended his impassioned plea by urging in the name of the People of the United States that deForest, Darby, and their associates be given the limit of the law and be sent to Atlanta Penitentiary.

The weary weeks of the trial dragged on through December and threatened to continue into the New Year. Several weeks before the trial began some of deForest's former classmates at Yale were approached and, sensing the injustice of the accusation, a "DeForest Defense Fund" was raised which defrayed the expenses of the trial; and an active crusading young attorney, Harold Deming, arose to defend the inventor, who, lacking this needed aid, would have been able to put up no defense whatever.

Thus the United States trial of Lee deForest went on through the Christmas holidays and did not terminate until the last day of the old year. It was noon of the last day, December 31, 1913, when the judge finally made his charge to the jury. The jury was out for thirteen hours. DeForest and Capt. Darby who had shared many experiences together sat in the old Federal Building, listening to the wild celebrations of the New Year outside. They were wondering whether the New Year would see them free men or felons.

The New Year was one hour old when the jury, heavy-eyed from their deliberations, filed into court. They had found Smith and Burlingame guilty; Darby and deForest were acquitted.

THE patent situations surrounding the inventions of Lee deForest, like those surrounding other important inventors, form a literature all their own, one that cannot be told in these chapters. There is, however, a human aspect to deForest's patent litigations. It centers about the inventor's earliest association, first with Captain S. E. Darby, and later with his son, S. E. Darby, Jr. It dates back to the first deForest patent application in 1900 and continues up to the present, forming an important part of the legal struggles, victories, and defeats that the inventor has undergone. Hence it cannot be considered lightly, nor too cursorily dismissed.

Captain S. E. Darby was a struggling patent attorney in Chicago when deForest first met him there in 1900, where deForest and Smythe had gone to the firm, Brown & Darby, to file their first joint patent application. The drawing up of this patent application was an event in deForest's life. He remembered Captain Darby when next he met that gentleman on the streets of New York years later and was indeed glad to learn that Darby had opened up an office in New York where he would most cheerfully file deForest's patent applications. From that time on Captain Darby or his son, S. E. Darby, Jr., have handled all of the deForest patent applications in radio and talking pictures, and other lines of invention, a group of United States and foreign applications totaling nearly three hundred. DeForest has written in his own words of his patent litigations and of the remarkable achievements of these two attorneys, a report which sweepingly sums up the legal complications across many years of invention and achievement.

"Ever since the disastrous patent litigation with the

Marconi Company over the Fleming valve in 1914, I have entrusted my patent matters to the firm of Darby and Darby, and for the past twelve years such litigation has been handled entirely by S. E. Darby, Jr. His success on my behalf in the United States Patent Office in prosecution of patent applications, in the winning of patent interferences, and especially in litigation in the Federal Courts, has been gratifyingly consistent and at times spectacularly successful. In this outside litigation Darby has had pitted against him the very élite of the patent bar, the best attorneys on the staff of the General Electric, Western Electric, Westinghouse and R. C. A. Corporations. He has to his credit a string of ten consecutive victories in the Federal Court in my behalf, or for the deForest Radio Company.

"The most notable of all was the historic litigation between myself and the Westinghouse Electric and Manufacturing Company, who owned the Armstrong patent and applications on the regenerative audion and feed-back circuit. The Westinghouse Company in 1919 sued my company, DeForest Radio, under the issued Armstrong patent, and won a sweeping decision from Judge Julius Mayer, whose findings were further sustained by the Court of Appeals in the Southern District of New York. But meantime patent applications by deForest, Armstrong, Langmuir, and Meissner had been joined in the patent office in Washington covering the fundamental principle of the feed-back circuit. Notebooks kept by myself and Van Etten, outlining the 1912 experiments in Palo Alto, were introduced in the testimony. We lost consistently in the Patent Office, appealing at last to the Court of Appeals of the District of

Columbia, which court found that my work of 1912 was definitely ahead of all the others."

Two patents of the broadest scope and incalculable value were issued to deForest as a result of these long drawn-out legal battles which raged for more than seven years. These two patents cover broadly the feed-back principle and circuits, whether for transmitting or receiving purposes, and completely cover the Armstrong patent which had been in the earlier litigation. Immediately upon this decision of the high courts, the deForest Radio Company proceeded in the Federal Court of Philadelphia to have the Armstrong patent declared invalid and non-existent. The Westinghouse Company attempted the same procedure in the Delaware district with the newly issued deForest patents, but were defeated. Whereupon they carried the issue up to the Supreme Court of the United States. This Supreme Tribunal of the nation finally held that deForest and not Armstrong was the original inventor of the feed-back circuit, thus terminating litigation which had extended in and out of the patent office for nearly fourteen years.

Not content with victories which put the name of Darby at the top among successful American patent lawyers, especially where radio patents were concerned, S. E. Darby, Jr., has continued to achieve new victories on behalf of deForest. In July, 1930, Judge Morris held that the patent of Reis covering the use of the "fine slit in sound-on-film reproduction" (which had been purchased by deForest when he found it dominated his own work) was valid, and infringed by the Western Electric Company. This victory marks the first entry of

Darby into the field of talking motion picture patents, where he bids fair, under the deForest banner, to win many new laurels comparable to those which he has acquired in radio litigation.

XII

It was back in 1914 that the turn of events in Radio gave deForest for the first time a sense of permanent achievement. In spite of the harassment of legal battles, of seeing himself tricked and robbed to such an extent that he derived only temporary financial relief from inventions that should have yielded a gigantic fortune, he knew that he had done something big, something worth while, something that was destined to go forward. The tide was coming in at last. Now nothing could stop the growth of this universal enterprise that he had helped to build. And he began to see for the first time that what he had suffered was perhaps but the natural expression of the resentment towards any great idea, the expression of the little people who control the money markets, who substitute shrewdness for intelligence, and who think, if at all, only in terms of dollars and cents.

Nothing could stop him now. No matter what they did, the idea itself would go forward, if necessary even without its creator. Even during that hideous trial that might have put him in a cell in Atlanta, with the $50,000 that represented one-tenth the estimated value of his invention, he had managed to get his directors

together and rehabilitate the Radio Telephone Company, changing its name to the Radio Telephone and Telegraph Company. Together with his loyal friend and tireless worker, Charlie Logwood, he rented a small factory and laboratory at Highbridge on the Harlem River, a spot destined to become famous in the subsequent annals of radio. Here it was that deForest and Logwood developed the first radio broadcast transmitter in 1916, an apparatus which Logwood later installed under deForest's direction as the first exclusively radio broadcasting station in the world, in 1920, at the California Theatre in San Francisco, from which station the first orchestra concerts in history were regularly broadcasted.

In January of 1914, freed at last from the deadening load that had hung around his neck for the past two years, deForest plunged with vigor into the task of developing the radio telephone and the audion amplifier. Even before this activity had begun to consume him, he called upon all those who had come to his aid during the trial, and paid a special farewell visit to J. C. McLanahan in Washington who had, first of them all, bestirred himself to help the inventor. McLanahan was glad indeed to learn that deForest had been freed, and advised him strongly to give up the idea that he was an inventor. "Find yourself a common garden variety of job and stick to it." DeForest thanked him profusely and went on his way.

Now at the Highbridge laboratory, deForest and Logwood turned their attention upon the improvement of the recently discovered oscillating audion with great enthusiasm and energy. The Navy had already become exceedingly interested in the amplifier and heterodyne

detector, and had begun to give the new company encouraging orders. DeForest's attitude of intensely loyal coöperation towards the Government continued, in spite of the latter's deliberate attempt to jail him. He realized the importance of taking each of his new inventions first to the Army and Navy for examination, so that these inventions could be included in the defence and armament schemes of his country. Ofttimes the apparatus ordered by the Government officials had to fulfill certain very difficult specifications, but the new designs were invariably made and the devices delivered on time.

DeForest further insisted that the company begin again to enlist the amateurs. In spite of insistence by the more commercially minded in his company that there was absolutely no money in the small mail order business and expensive show room display, deForest declared that it was absolutely necessary to keep the experimenters interested and to give them all the help possible in their hobby. He called them the "true scientists" of the radio industry, caused successive catalogues to be issued, and watched for the discoveries and comments on the part of the ever-increasing army of "hams" with an interest second only to that shown in his own laboratory problems.

In the Summer of 1914, the indefatigable young lawyer who had bought the rights to the audion amplifier appeared again, this time asking deForest to call at his office to see him regarding a matter "of the greatest interest to deForest." The young man was as dapper as ever in his clothes, as suave in his manner; but now the air of honesty and conviction, chiefly an expression on his face, had faded out somewhere in his successful manœuvres. For in its place was an expres-

sion more indicative of his character and personality, a broad and deadly smirk, that knew no abashment. This time he very frankly informed the inventor that the American Telephone and Telegraph Company had further interest in his patents. This time they wanted the radio rights, and he had been authorized to offer the sum of $25,000 for these rights! DeForest informed him offhand that $100,000 was the least his company would consider. A compromise was finally effected in the figure of $90,000, conveying licenses to radio rights also to the Telephone Company, thus giving them the use of the amplifier for wireless in addition to wired telephony.

With this additional $90,000 the company's work went ahead more rapidly. The Highbridge factory was immediately equipped with more machinery. A vacuum lamp pumping plant was installed. The manufacture of audion tubes, first small ones and later large transmitting tubes, was begun in earnest at last and under deForest's own name.

Since one of deForest's penchants was the attendance of himself and the members of his company at all expositions of world-wide interest, new plans were made for the coming Panama-Pacific Exposition which was to be held that year at San Francisco. The glimpse at the scientific horizon afforded by these expositions gave him again something of the old enthusiasm that had animated him at his first exposition and at St. Louis in 1904. He determined to have one of the most interesting booths on the grounds.

Meantime, the Telephone Company, now armed with their long desired rights for going into radio under deForest's patents, began immediately a much more

ambitious scheme. They were not only putting the finishing touches on a transcontinental telephone line between New York and San Francisco, which was made possible in a measure by the use of the audion amplifier as a telephone repeater, but they were also constructing large numbers of huge "power audions" and, it was rumored, had entered into a contract with the United States Navy for installing these in a high power telephone transmitter at Arlington, near Washington.

At the Panama-Pacific Exposition, deForest and his associates erected one of the most interesting booths to be found anywhere on the grounds. He was thrilled as always at the sights and sounds of the exposition — until the Telephone Company publicly announced that they had completed their transcontinental telephone line between New York and San Francisco, and sent out their invitations for a public opening with a great fanfare of publicity.

The telephone booth at the exposition was arranged in gala attire. There was a huge set of apparatus and an endless array of booklets to tell the awed reader how this great feat of engineering had been accomplished. Many distinguished officials and men of affairs were invited to witness the solemn ceremonies. But Lee deForest, whose inventions had made possible the opening of the line, and whose inventions had been bought for ten per cent of their appraised value, received no invitation. Nor was one word of credit given either to him or to the audion in any of the newspaper articles or publicity material emanating from the American Telephone and Telegraph Company.

Where indeed was the little tube which had made the accomplishment possible — the audion? Apparently there was no such tube. The most important publicity of the telephone booth was a booklet entitled, "The Story of a Great Achievement." It told simply how "the engineers of the Telephone Company had been striving for a long term of years for the feat which had at last been accomplished," and then went into some mechanical details as to how the thing was done, giving not the slightest reference to the audion amplifier!

Upon reading this little booklet, deForest sat all that night in his room in the St. Francis Hotel and wrote his own story of the great achievement, which he completed and had printed in three days. His own pamphlet was purposely so similar to that given out by the Telephone Company that the two from the outside were almost indistinguishable. The text, however, was very different. It went into great detail as to the use of the vacuum tube as an amplifier of telephonic currents; told the exact location of the various relay stations; and explained thoroughly the problems which had been solved by the deForest three-electrode vacuum tube! These pamphlets were circulated and widely read. DeForest was content, for he felt the inevitable scientific loop-holes in the Telephone Company's pamphlet had been filled in by his own, and the truth given its chance to go forward.

A story is told of how the press got wind of the fact that the audion was in use and had made possible the transcontinental line, and confronted officers of the telephone company, but these gentlemen coolly informed the inquiring reporters that "nothing invented by deForest was used in long-distance telephony."

THE progress on the high power radio telephone transmitter went on apace through 1915. Tests were conducted from Arlington to Honolulu and to the Eiffel Tower in Paris. In November, 1915, the public announcement was made that the human voice had been transmitted from Arlington across the Atlantic and half way across the Pacific, thereby realizing the prophecy which deForest had made to the newspapers five years before, and chiefly for which he had been arrested and threatened with prison sentence!

It was a new day, a new age — and anything might happen. The scientist's ideas as to the future of electricity were no longer held up to ridicule, and the fact that one of them had been arrested for his prophecy seemed almost as remote as the Inquisition. But it all was very true just a few years past.

And since the year of deForest's trial for seeking to interest the public in the $2,000,000 company owning his audion patents and inventions, the radio and telephone wealth earned by the various licensees under these same patents and their successors is conservatively estimated at over one billion dollars! And yet the dollar sign is a crude and ill-adapted unit by which to determine the immeasurably finer values of radio to mankind.

The World War in 1914 brought about more intensive development of the audion and its various applications, including radio transmitters and amplifiers. The result was that the art advanced in two years more rapidly than it would have in five years of peace. Since communication was one of the most important phases of the campaign, radio leapt into super-importance, as it were, over night.

During that period while one of the great Zeppelin scares was harrowing the hearts of the non-combatants, deForest, who happened to be in London at the time (it was November, 1915) and who knew the characteristics of the transmitted sound of the Zep engines, set to work to find some means of protecting the cities and villages by the simple expedient of giving them warning long enough in advance to seek safety. He fixed a microphone in the small end of a huge megaphone, ran the leads of the microphone to his three-stage audion amplifier, and equipped the horn with a swivel joint so it could rotate in any direction. This arrangement allowed the Zeppelins to be detected and located while still far away.

It was a time of great pressure and great things in his own country. The war had settled down to a steady grind and all the combatants were aware that the final outcome greatly depended on communication. DeForest had barely returned to America before he was pressed into the work of designing and executing transmitters and receivers for the Allies, as well as developing radio apparatus and methods of using the apparatus both in the firing lines and at the bases. Some tens of thousands of young men, already great enthusiasts of radio, were being trained as wireless operators. Most of these men continued their interest in radio, built transmitting and receiving sets of their own, and were in the market for purchasing all kinds of condensers and coils and other radio equipment. Consequently deForest was called upon to answer the demands of the amateurs more than ever before. Commissions came thick and fast, keeping the deForest organization working at top speed. Experiment had to be carried on between regular production

periods. Nevertheless the oscillating audion gained foothold as a generator; the use of the little tubes as amplifiers was becoming more and more common.

In the summer and fall of 1916, while still engaged in war work for the Allies, deForest started what is considered by the layman to be the first regular broadcasting. The first of the programs were placed on the air from the Columbia Phonograph laboratories in New York City, consisting chiefly of that company's new records, and picked up by a notable group on the roof of the Hotel Astor where a number of celebrities were celebrating the occasion. At the dinner table were placed many pairs of regular telephone receivers with headbands which were connected to a standard receiver and amplifier. The program came in strong and clear. Next morning the press heralded the event with big headlines. DeForest saw that radio might now at last become an actual public service which could be enjoyed by everyone. Artists who had been engaged to make records now appeared before the microphone. New interests were added to the program. Before long, letters began to pour in praising the station's service and asking for more.

Then the station was moved to Highbridge. DeForest began to go ahead with his broadcasting with keen enthusiasm. He arranged the first "radio dance," the music for which was played in Highbridge and reproduced in a wealthy home in Elizabeth, New Jersey, through amplifiers which were placed where the guests danced. The first use of the radio broadcast for dissemination of news was in the presidential election of 1916, when the New York American ran a special wire to the deForest plant in Highbridge and broadcast news bul-

letins from hour to hour. At the closing, Lee deForest, radio's first announcer, informed his public that "Charles Evans Hughes has been elected President," only to be contradicted by next morning's newspapers!

DeForest was probably the original broadcast announcer. He personally made many of the announcements in the early years, though his engineers took regular turns at the microphone night after night. This early broadcasting aroused a tremendous amount of interest throughout the East. It was heard in Toronto, Canada, and by ships far out at sea, resulting in an increased demand among amateurs for the deForest products. The company's business was growing rapidly up to the beginning of 1917, when the gathering war clouds compelled the government to shut down on all amateur radio activities, a ban that was not removed until the Spring of 1919.

Shortly after this ban lifted, in 1919, deForest removed the transmitter from the Highbridge plant to the World Tower Building, where he worked on an even more elaborate scale than ever before. There, for the first time, regular vaudeville entertainment was broadcast. Vaughn Deleath, a well-known singer, was the first "radio girl." She sang and talked over this station in December, 1919, and has a wealth of fan letters recounting the pleasure in receiving her voice.

FROM 1920 on, radio broadcasting rose swiftly into the gigantic industry that it is today. The "early days" were over. The memories of the long struggle to convince financiers and industrialists that here was something more than a hazy dream receded further and fur-

ther into the background, as great organizations began to suck up those many and varied devices, coming mostly from the minds and workshops of isolated men of science who have made radio possible.

According to Lee deForest, however, the moving force behind this marvelous new means of communication cannot be traced to the great organizations which today control the radio industries. Not even wholly to the inventors whose ideas, interlinking one with the other, have flung radio across these thousands of miles of space. To whom, then? To the American Amateur, who was willing to toil and discover alone, without any thought of reward, for the sheer fun of the game! Of him Lee deForest has spoken often. Part of his words written to Hiram Percy Maxim follow:

"Had it not been for the American Amateur there could have been no Radio Broadcast, and no radio industry as it exists today. To one familiar with the actual conditions existing fifteen years ago this truth seems self-evident. The world at large, the Radio Industry with its $600,000,000 annual turnover, little realizes this fact. If they did then the world and the industry would today be erecting memorial tablets and dedicating monuments of appreciative recognition to the Radio 'Ham'; instead of seeking at Washington to strip from him what scant vestige remains of the once wide and unexplored regions of short-wave channels, then considered by commercial interests as worthless, which he first proved valuable.

"These youths, the Magellans and DeGamas of Radio, toiling sleeplessly through unnumbered nights, explored new seas of ether and discovered there uncharted realms of communication where commercial

interests had refused to enter — yet how quick thereafter to seize and claim for their own! And on how many occasions have these tireless amateurs alone heard the faint S.O.S. from some sinking vessel, or alone been the means of communication with some explorer's expedition lost to the world save for them?

"What the technique of modern short-wave radio owes to our Amateur the world is never told, or is loath to admit. Discoveries which the paid commercial engineer would never dare attempt to make, simple and compact constructions which only poverty, necessity, and an untutored common sense could ever evolve, have time and time again emanated from the Ham's workbench, to confute and confound the professional into speedy confiscation. All these things, priceless in themselves, we owe to the amateur.

"But more than these material gifts we owe to him the invaluable spirit of discovery, of wide-awake experimentation not shackled by the book knowledge and predetermined notions of the engineer; of youthful enthusiasm, the tireless spirit of quest — that which was chiefly responsible for radio at its inception, and for its matchless rapidity of growth. This spirit alone is priceless.

"And little does the amateur ask in recompense for all this. Merely to be left alone in a now cramped cranny in the wide fields of higher frequencies which he discovered and gave to mankind."

On his trip to Paris in 1918, on board the U. S. Army Transport *Carmania,* deForest told his friend and patent attorney, Sam Darby, Jr., a strange piece of

news. He had been dwelling for some time past on the subject of talking motion pictures, to which he intended to devote more and more of his time in the future. His inventions in the talking picture field, the Phonofilm, as he had already named it, were now at that point where, in a year or more, they would consume all his attention. The beginnings of commercial interest in broadcasting, along with certain other developments in his affairs, would, in two years, leave him free to continue his investigations in this fascinating new field of entertainment.

Darby was at first stunned by this news. After all that the name of deForest had stood for in radio, to leave the art just as it was at last coming into its own, after a struggle that had taken in the greater part of the inventor's life, came as a great shock to his friend. Now, after the battle had been won, after the city had been built — to leave it seemed almost incredible!

And yet, that was just what deForest was doing — leaving behind the city he had helped to build out of a wilderness. Darby was at first inclined to discourage him, but deForest took the latter down to his stateroom and revealed, for the first time, his inventions in the field of talking motion pictures, showing his drawings and notebooks and holding forth upon the newness of this idea. Darby saw and marvelled. Here were amazing inventions in the raw. The talking picture was undoubtedly a fascinating project, and it had the added attraction, unlike radio, of being entirely new.

And so, in 1920, just as deForest had prophesied he turned his attention completely to the development of the talking film. He began a two years' investigation which ended in the latest great invention accredited to

his name, the Phonofilm. His friends in the radio industry, foreseeing that they were about to lose one of their greatest inventors, the foremost pioneer, arose in alarm. They could not understand how one who had fathered an idea while it was in its swaddling clothes, an idea to which he had given so much of his power and energies, should turn his back upon it just when he should stay and reap the glory.

They could indeed not comprehend the motive in deForest's mind when in the fall of 1921 he moved his family and laboratory to Germany, encompassing himself and his ideas behind the four walls of a laboratory in a strange land. They could not see that the Pioneer in deForest had asserted itself again, anew, after all these years, forcing him on from the flourishing cities of the conquered land again towards the prairie sod. There the winds might howl and the ground beneath his feet be frozen hard, but there alone could he find that deep and tingling thrill of not knowing what was just ahead. The Pioneer was striding on!

PART SIX

THE PHONOFILM

I

A SINGLE year in his laboratory in Germany brought deForest amazing results. He had succeeded in making practical talking moving pictures.

This time his return to the native land of his great achievements was heralded by press and public alike.

In view of the transformation these talking picture inventions have wrought throughout the fourth largest industry in the world, it might prove interesting to look back on that period, 1921 to 1923, when the idea of talking pictures was equally alien to Broadway and Hollywood.

The newspapers of 1922 proclaimed the homecoming of deForest and the talking picture. In the *World* of May 6, 1922, appeared one of the earliest announcements of "Light and Sound Filmed in One and Movies 'Talk.'" It read:

"The greatest revolutionary inventions of the decade have been announced by Lee deForest, pioneer in wireless telegraphy and the radio telephone.

"Spoken drama on the film has been achieved. And a super-phonograph that will play from films!

"Dr. deForest, making his first detailed explanation

of his inventions, forecasts a new movie epoch that will include:

"A tremendous stride in educational films that will be vocal instead of visual — a talking explanation simultaneous with the pictures.

"Introduction of all the dramatic art of the spoken drama in the movies — the end of the movie actor who has nothing but a good 'camera face.'

"Unlike the talking movies of Edison and Kellum, Dr. deForest's invention, which he plans to demonstrate here within six months, has none of the faults or limitations encountered in using the phonograph synchronized with the movie film.

" 'I have simply photographed the voice onto an ordinary film,' he said. 'It is on the same film with the picture, a narrow strip down one side, so narrow that the picture is not spoiled.'

"The talking film can be shown with the projector now in use in movie theatres by simply adding my sound-reproducing device. It is a small box that can be adjusted in half an hour.

"This device translates light waves into sound waves, which are amplified for all to hear.

"Talking pictures can be taken with an ordinary camera reconstructed to translate sound waves into light waves. Around the studio sound-recording devices are placed, ten or twenty feet away from the actors. Voices are amplified and sent into the camera where they are traced in the side of the film through a narrow slit one one-thousandth of an inch wide. The intensity of the light fluctuates exactly with the sound waves, which become light waves black enough to print. The voice radiations are developed at the same time as the picture.

"Dr. deForest agreed, smiling, that this meant the end of the present megaphone methods of motion picture directors.

" 'They'll have to direct pictures by the sign language,' he said. 'What will happen is that they will have to use real artists — actors who have a voice as well as a camera face. I think it will add brains to the movies.'

"As the inventor foresees it, the talking movie will differ from the spoken drama in that there will not be continual conversation.

" 'There will be spaces of silence when the action of the picture requires no talking,' he said. 'It will liven up the movies for it will do away with titles. When it is necessary for a character to say something he will say it.'

"The phonograph film he has invented probably will not be perfected for two years. He explained that it probably never would come out of the luxury class, since the special machine required will cost at least $1,500 and film records from $20 to $25 each."

On March 13, 1923, under the headline of "Public Soon to Witness Talking Film," the New York *American* carried this story:

"I sat in the dim New York studio of Lee deForest, inventor, today and heard music on the silver sheet. As I watched the movie of an orchestra performing, I heard the music it made.

"Piano, flute, clarinet, cello — I could distinguish the notes from the several instruments. The music played came from out of nowhere, from the direction of the screen. Measure by measure, it harmonized exactly with the movements of the shadow players.

"For before my wondering eyes and ears was being demonstrated for the first time the Phonofilm, latest addition to the world of inventive genius and the brain child of deForest.

"It was the talking motion picture perfected at last.

"Today's demonstration was for the benefit of the press. In a few weeks the Phonofilm, after four years in the making, will be introduced to the public in a number of the metropolitan motion picture theatres.

"I asked if the invention meant that movie drama would be 'spoken.'

" 'Not for a while at least,' deForest replied, 'because dramas are especially written for the screen and are designed to be without the human voice. But forward-looking screen writers will evolve something for the application of the Phonofilm to drama.'

" 'We mean to film the music of large orchestras to be incidental to all kinds of films. It will be a wonderful treat to people of small towns to hear music with picture plays, music produced by the best orchestras of New York.' "

At the same month of the same year appeared another item concerning deForest in his old rôle as "father of radio." Under the headline, "Auto Interests Buy deForest Radio Company," the New York *Times* carried the following story:

"Plans of the automobile makers to enter into the manufacture of radio equipment were disclosed yesterday when Charles Gilbert, President of the DeForest Radio Telephone and Telegraph Company, announced that a controlling interest in his company had been sold to automobile interests of Detroit and bankers of Chicago and New York.... The new company will retain

the services of Dr. deForest for a period of ten years as consulting engineer, with the rights to his radio inventions during that period."

The sale of his capital stock in the old company lifted a great load of business responsibility from the inventor's shoulders. It was not without result. In December, 1923, came the announcement that Phonofilm was ready for the trade.

"DeForest and his corps of technical assistants as well as theatrical advisors have labored day and night, adding refinements to make the scientific marvel an entertainment marvel as well. Countless experiments have been made, hundreds of productions, each day bringing its improvement. A few weeks back it was the consensus of opinion among those who have been closely associated in the development of the Phonofilm that the necessary quality for theatrical circulation had been reached."

The spring of that same year, April, 1923, saw the first showing of deForest's Phonofilm at the Rivoli Theatre, where Hugo Reisenfeld had been quick to envision the future of the talking picture and had readily put it on his program.

In view of the situation in the motion-picture industry today it is highly interesting to note that the critics of 1923 were either lukewarm or else disparaging. One critic who witnessed the first showing, Karl Kitchen, wrote under the headline, "New Talking Picture Is Shown — But What of It?" He continued: "Another 'talking movie,' this time a synchronization of music and pictures on the film, was shown for the first time at the Rivoli Theatre last Sunday. The invention, which is called the Phonofilm and which has been

perfected by Dr. Lee deForest, does all that is claimed for it. The action and the sound synchronize perfectly — but what of it? The music sounds like ordinary phonograph music which is very different from that of a symphony orchestra, to put it mildly. . . . Besides, the theatre-going public has not evidenced any interest in talking pictures."

When newspaper feature writers questioned Hugo Reisenfeld as to what he thought of the future of the talking pictures, Reisenfeld replied, "That is best answered by the fact that I ran them for three successive weeks at the Rivoli. That my confidence was not misplaced is evidenced by the comments of approval from our patrons. The pictures have attracted great attention. They have a great future."

Then a more elaborate idea was put into effect, banishing in its glory all predictions as to the probability of talking pictures being a temporary fancy, destined to disappear with time. Reisenfeld announced that he would give a special showing of two reels of "The Covered Wagon," with the Criterion musical accompaniment photographed on the film, and perfectly synchronized with the action through the medium of deForest's Phonofilm. It was a great success, this first of all "and music" films. There were reports of negotiations pending between Dr. deForest and officials of big moving pictures companies for using the Phonofilm musical accompaniment throughout the country.

Meantime, behind the scenes, the scientific development of Phonofilm had swept on apace.

From his very earliest experiments in recording

sound on film in 1919, deForest had used a thalofide photo-electric cell, the invention of T. W. Case, an experimenter and inventor of Auburn, New York. Shortly after his return to New York, after his year in Germany, as soon as he had re-established his laboratory in October, 1922, deForest invited Mr. Case, for whom he had great respect, to come down and see what he was doing in talking pictures. The minute the two scientists came together they found each other's ideas engrossing. A close association resulted. They drew up a contract, and Case came down from his laboratory in Auburn to work with deForest. In spite of the remarkable results deForest had obtained working alone, with the aid of Case, he was now able to speed up his results.

In the course of this association between the two inventors, according to the entries in deForest's notebooks, Case naturally became familiar with all that deForest was doing, and had invented, including all the patent applications which he was taking out on his various new devices, just as deForest became familiar with many of Mr. Case's ideas. The contract between Case and deForest terminated in 1925, long previous to which time Case, who had a laboratory of his own in Auburn, began, with deForest's written permission, to experiment along lines similar to those of deForest. In the course of these experiments Case developed an improved design of photion, or gas-discharge tube, useful in recording sound on film, but, according to deForest, under deForest's basic patent and following exact designs suggested by deForest. These gas-discharge tubes, or photions, as well as Case's thalofide cells, were used in the deForest Phonofilm until 1925 when the contract between the two expired, at which time deForest had

determined that the improved type of gas-filled photo-electric cell was much more sensitive to the higher frequencies of sound than was the thalofide cell. Moreover the arrangement with Case having terminated, deForest no longer used Case's tube for recording sound, but one of his own design.

The deForest version of the complicated talking-picture-patent situation is this: After the termination of this contract with Case, deForest heard nothing further from Case other than that the latter was making talking pictures in Auburn and exhibiting them in Auburn theatres with equipment based on that which deForest had loaned to these theatres long previously. Nevertheless deForest made no move to stop Case, whose ideas had after all proved useful, until one year later in 1926, deForest learned that Case had set up his reproducing equipment in the Fox studios in New York. As a result of this demonstration Case had succeeded in interesting William Fox, who not knowing deForest's end of the patent situation, had immediately entered into contract with him and formed the Fox-Case Company to make pictures and exhibit them in the Fox Theatres under the title of "Movietone." DeForest observed with amazement that this name, Movietone, was, in his estimation, the chief distinction between the Case pictures and the deForest Phonofilm pictures. He immediately brought suit against the Fox-Case Corporation for infringement of several of his patents. This patent suit has not yet come to trial in the Federal courts.

Further, deForest's interests filed another suit against the Stanley Company of America and the Western Electric Company, claiming infringement of the basic

"slit patent" which deForest had purchased from Elias Reis in 1925. DeForest actually had independently invented and had been using the "fine slit" invention since 1920, both in recording and reproducing, knowing nothing of the Reis patent applications until 1924 when the first Reis patent was issued. Whereupon, immediately recognizing the great value of this patent he had entered into negotiations on behalf of the DeForest Phonofilm Corporation to purchase the Reis slit patents. These Reis patents are the ones which have just been sustained by the United States Federal Court.

From April, 1923, to 1927, deForest and his associates had repeatedly attempted to interest the leaders of the film industry in the possibilities of the Talking Picture. But all in vain. Adolph Zukor, William Fox, Carl Laemmle, one and all had witnessed his demonstrations in studio and theatre, but without exception had decided that they or the public did not want the Talking Picture. They dreaded the total upheaval involved, the scrapping of the art of the silent film which they had spent years in developing. They foresaw the threatened failure in spoken dialogue of the many artists without adequate recording voices or vocal technique upon whom they had spent hundreds of thousands of dollars to establish as stars of the screen.

It was not until the Warner Brothers had decided to risk their all in a talking picture venture (sound on discs synchronized with the film) and plunged into this venture in the summer of 1926, that the motion-picture magnates began to realize that here, along this line of progress again pioneered by deForest, lay their future fortunes. But since the amazing success of the Warner Brothers, the motion picture industry has moved on

apace without credit to the name of deForest, whose solid work in his Highbridge laboratory and in Germany, together with his earlier inventions which culminated in the audion amplifier, the most important implement in the recording of talking pictures, contributed so largely to this modern field of entertainment.

Nevertheless the progress in his Phonofilm laboratory has been steady and consistent so that now deForest is preparing to settle permanently in Hollywood where a subsidiary of his organization, the General Talking Pictures Corporation, will develop his most recent inventions in their own talking picture productions, or those of their licensees, inventions that will perhaps astonish even the blasé personnel of Hollywood. It is deForest's opinion that the thousands of motion picture lovers who have seen and heard the latest news weeklies and symphonic musical accompaniments to feature films, have seen only a suggestion of the radical changes bound to occur in the talking picture of the future. Just as advances in photography and pictorial effect which were not conceived of a few years ago are now commonplace in the minds of producer and public alike, so undoubtedly the film of the future will be a masterpiece of the speaking voice, subtly adapted to the development of the character portrayed on the screen, with color and music that will make our most modern motion picture seem primitively small and dull.

A present and very promising deForest project is the talking movie for the home. For some time past he has been devoting his personal attention chiefly to the problems of the Phonofilm or talking pictures in 16 m. m. film. For this purpose it has been necessary to develop

a different type of photo-electric cell, much smaller than that used in the theatre projectors, and a very efficient amplifier which is small, compact, requiring practically no attention or adjustment and at the same time cheap to manufacture. It appeared obvious to deForest that to make the 16 m. m. Phonofilm commercially practical it was necessary to keep the cost factor down in every possible manner. It was at first considered desirable to utilize the existing radio audio-amplifier which can be found in almost every home having a motion picture projector, but careful consideration of the problem finally persuaded him that the most suitable method would be to work entirely independent of the radio outfit in the home, to use his own amplifier especially designed for the purpose, a special loud-speaker which could be located directly behind the projection screen on the wall, or in whatever part of the room it might be most desirable to erect the screen. His work along these lines has at length begun to bear fruit, and from present indications it is highly probable that the public will see on the market in a short time a 16 m. m. sound-on-film attachment which can be readily installed on modern types of home projectors, at a very reasonable cost.

II

It is one of the sad facts of an inventor's life that his inventions are rarely ever put to the purpose for which he intended them.

DeForest was correct in his prophecy that radio would knit the entire world in a huge network. But he went further, into the far-flung realm of the idealist. He believed it was destined to educate and uplift humanity by bringing to every man a daily supply of new impressions of broader scope than any yet dreamed of.

The very word "radio" was to Dr. deForest a symbol of speed and world-wide activity. Other men walked down a street and saw only a street filled with people. He saw a different picture: Piercing the bodies of tall buildings, down through empty halls and crowded halls, through stone and mortar and steel framework, on out again into the streets where men and women are walking, through their clothes and their flesh, through traffic so thick that not a taxi-cab can move, past thousands of signals, words and sounds at a rate of speed too swift for the human mind to contemplate. It is the architecture of space, built by the scientists and engineers of the past half century, among whom Lee deForest stands at the front of the rank.

Whereas the perversion of present-day radio moves the inventor to cry out in despair. For instance, on the night of January 5, 1930, when Lee deForest was made President of the Institute of Radio Engineers his inaugural address contained a few ideas that caught the attention of the press. DeForest declared that "the present all too marked tendency of the broadcast chains and of many individual stations to lower their bars to the greed of direct advertising will rapidly sap the lifeblood of this magnificent new means of contact which we engineers have so laboriously toiled to upbuild and perfect. How often do you hear over your radio an announcer informing you that you 'have just heard Beethoven's Ninth Symphony, played for you by courtesy of the Venus Dishpan Company, manufacturers of the famous Venus dishpan and other famous products'?" The helpless layman is not the only one who writhes when good music ends with some such advertising nonsense. The radio engineer detests it just as much because he fears it will drive the public away from radio and render the engineer's work useless." Where, he wanted to know, was the practical realization of the dream that had inspired him and many another engineer and scientist to devote his life to radio? Where indeed was that "Parliament of Man" which radio was destined to bring appreciably nearer to reality? He challenged the engineers to make it come true!

One possible answer to this challenge came just sixteen days later in the form of well-nigh perfect transmission of the opening ceremonies of the London Naval Conference to every part of the United States. It was much more than a feat of radio broadcasting. It was also a great public service, rendered freely and for its

own sake — a service which brought the nations of the world closer together and furthered the cause of universal peace. Those who rose early on the morning of January 21, 1930, and listened to the voices of the King of England, the Premiers of Britain and France, the American Secretary of State, the representative of the King of England, the Premier of Japan, coming all the way from the House of Lords in London, felt a certain eerie sense of being present at a drama of international scope, of being there to listen as the four corners of the earth drew closer together.

It is interesting to note that the Parliament of Man made its first practical appearance before the multitudes of the world not through the strategies of statesmen but rather through the quiet work of the scientist in the form of small glass tubes hidden far from sight, the audions of Lee deForest. And the inventor of the audion, listening over his breakfast coffee to the clear concise words of the Premier of England, felt that his contribution to radio had indeed been used for the purpose for which he intended it.

It seems only just that the audion should have won for its inventor many honors. Included among these is the Elliott Cresson Medal of the Franklin Institute, after a special committee had reported that "the invention of the three-electrode vacuum tube is one of the most important ever made in the field of electrical transmission of intelligence, and through its development has worked a profound revolution in the art of radio communication." Among other honors to deForest may be listed the John Scott Medal of the City of Philadelphia, the Prix Saint Tour of the French Academy, the Medals of Honor of the Institute of Radio Engineers,

Gold Medals of St. Louis and San Francisco World Fairs, honorary degrees of Doctor of Science from Yale and Syracuse Universities, Sigma Xi, Aurelian Honorary Society of Yale, the Synton of the University of Minnesota, and the Cross of the Legion of Honor conferred by the French Government in recognition of the great services of the audion to the armies of France during the World War. He is a Fellow of the Institute of Electrical Engineers, Fellow and President of the Institute of Radio Engineers.

Today the restless eagerness in his eyes, his apparent youth and the vitality that emanates from the "Father of Radio," despite his fifty-six years and his white hair, mark him as one who indeed believes there are still important things to be done in the world. There is, for instance, a fight still to be waged against the use of the ether merely for dreary dollar-chasing. Today, in his Spuyten-Duyvil home on the Hudson, frequently horrified at the "entertainment" coming in nightly over his radio, deForest devotes a portion of his time to protests or writings that flay the existing broadcasting programs. Those who know him wonder at his remarkable optimism that has persisted and will continue to persist, despite experience and despite the years.

Part of this very noticeable characteristic in the "Father of Radio" may be explained by his close attention to his physical well-being. It is his pride that every morning for the past fifteen years he has risen at seven o'clock, spent many minutes in setting-up exercises and eaten exactly the same breakfast: two poached eggs, corn muffins, and a glass of milk. He uses neither cigarettes nor coffee, having determined that both of these are harmful to him. Each morning as Dr. deForest

enters his laboratory he finds himself just as excited about the problems there awaiting solution as he was back in 1900. His week is not complete unless he hears at least one symphony concert or an opera. He is interested in television and confers from time to time with the outstanding workers in that field. He follows closely those multiple and marvellous by-products of radio, apart from the more-or-less set path of radio broadcasting, which suggest to the scientist new cities, new worlds. It is this vision, of a new world which compensates the inventor for all his struggles, if only because it cannot be patented and no one can steal it away.

THE END